

Network Systems
Science & Advanced
Computing
Biocomplexity Institute
& Initiative
University of Virginia

Estimation of COVID-19 Impact in Virginia

October 20th, 2021

(data current to October 16th – 19th)

Biocomplexity Institute Technical report: TR 2021-111



BIOCOMPLEXITY INSTITUTE

biocomplexity.virginia.edu

About Us

- Biocomplexity Institute at the University of Virginia
 - Using big data and simulations to understand massively interactive systems and solve societal problems
- Over 20 years of crafting and analyzing infectious disease models
 - Pandemic response for Influenza, Ebola, Zika, and others



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Overview

- **Goal:** Understand impact of COVID-19 mitigations in Virginia
- **Approach:**
 - Calibrate explanatory mechanistic model to observed cases
 - Project based on scenarios for next 4 months
 - Consider a range of possible mitigation effects in "what-if" scenarios
- **Outcomes:**
 - Ill, Confirmed, Hospitalized, ICU, Ventilated, Death
 - Geographic spread over time, case counts, healthcare burdens

Key Takeaways

Projecting future cases precisely is impossible and unnecessary.

Even without perfect projections, we can confidently draw conclusions:

- **Case rates in Virginia continue to decline, with nearly all districts declining as well; case rates remain high and the rate of decline remains steady**
- VA 7-day mean daily incidence is slightly down to 24/100K from 29/100K; US is also slightly down to 25/100K (from 28/100K)
- Projections show continued decline across the board
- Future case growth remains possible, however, when tested with transmission drivers from last year
- Recent updates:
 - Analysis to show potential impact of Influenza based on past seasons
 - Updated vaccination schedules, adjusted 3rd dose uptake and 5-11 year old timing
 - Adjustment to higher levels of assumed immunity waning (natural and vaccine)

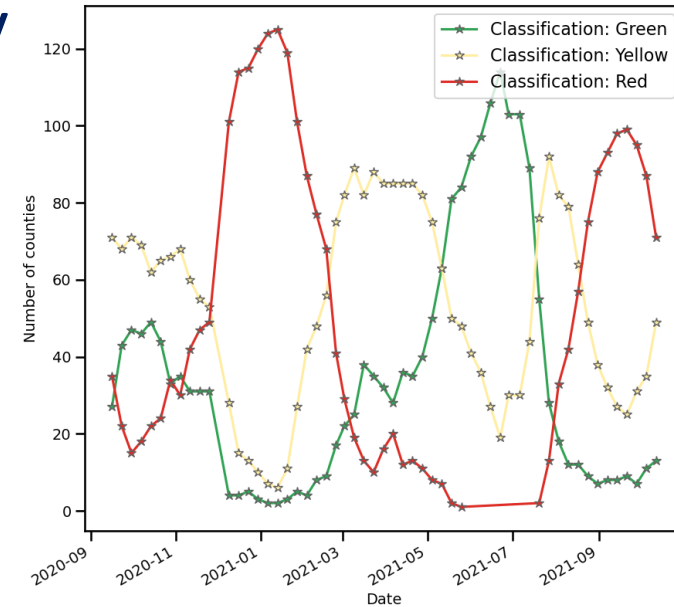
The situation continues to change. Models continue to be updated regularly.

Situation Assessment

Case Rates (per 100k) and Test Positivity

- Case rate increase across all health districts
- Some past 50% of winter peak and growing
- More than 50% of counties with TPR > 10%

Data source: <https://data.cms.gov/covid-19/covid-19-nursing-home-data>

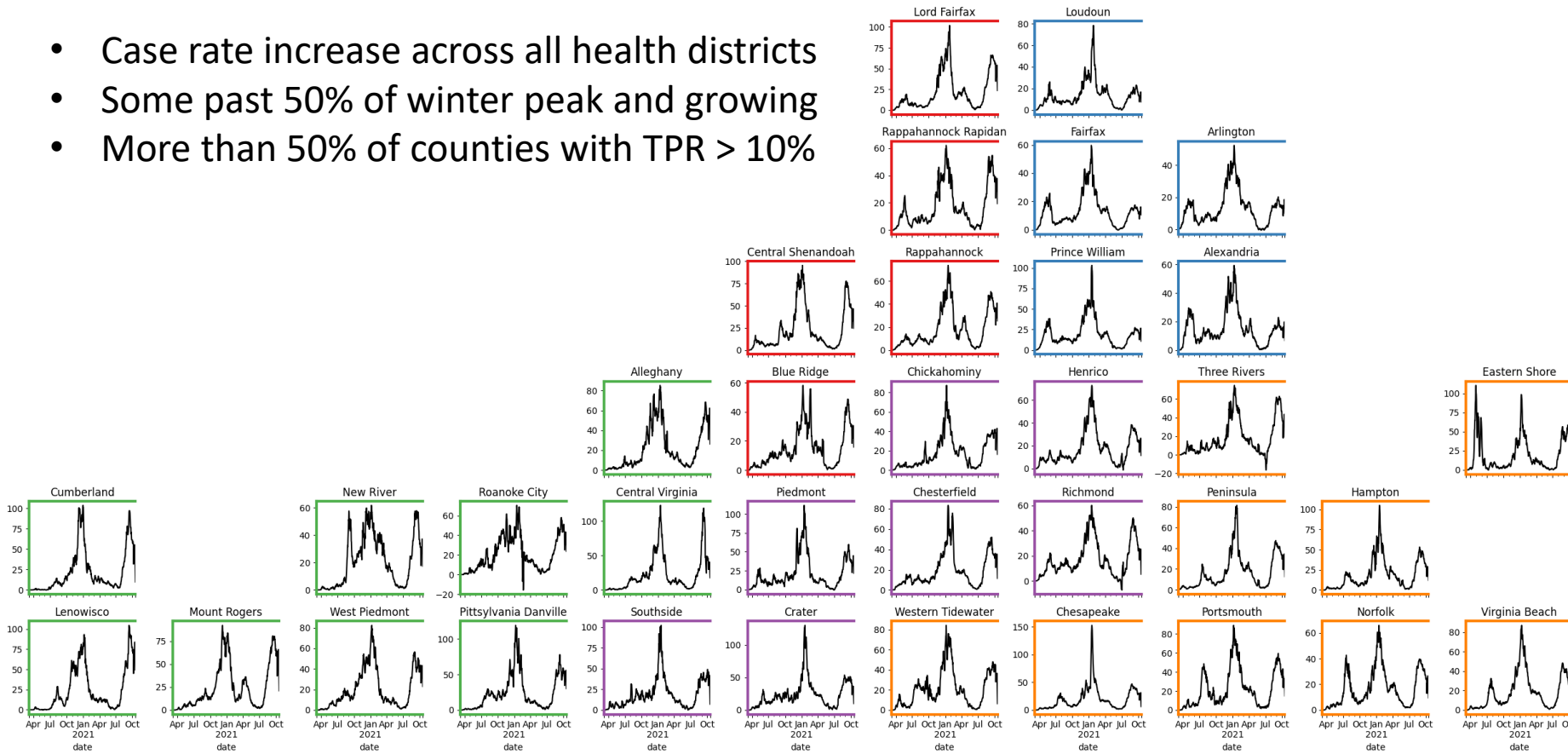


County level RT-PCR test positivity

Green: <5.0% (or <20 tests in past 14 days)

Yellow: 5.0%-10.0% (or <500 tests and <2000 tests/100k and >10% positivity over 14 days)

Red: >10.0% (and not "Green" or "Yellow")



District Trajectories

Goal: Define epochs of a Health District's COVID-19 incidence to characterize the current trajectory

Method: Find recent peak and use hockey stick fit to find inflection point afterwards, then use this period's slope to define the trajectory

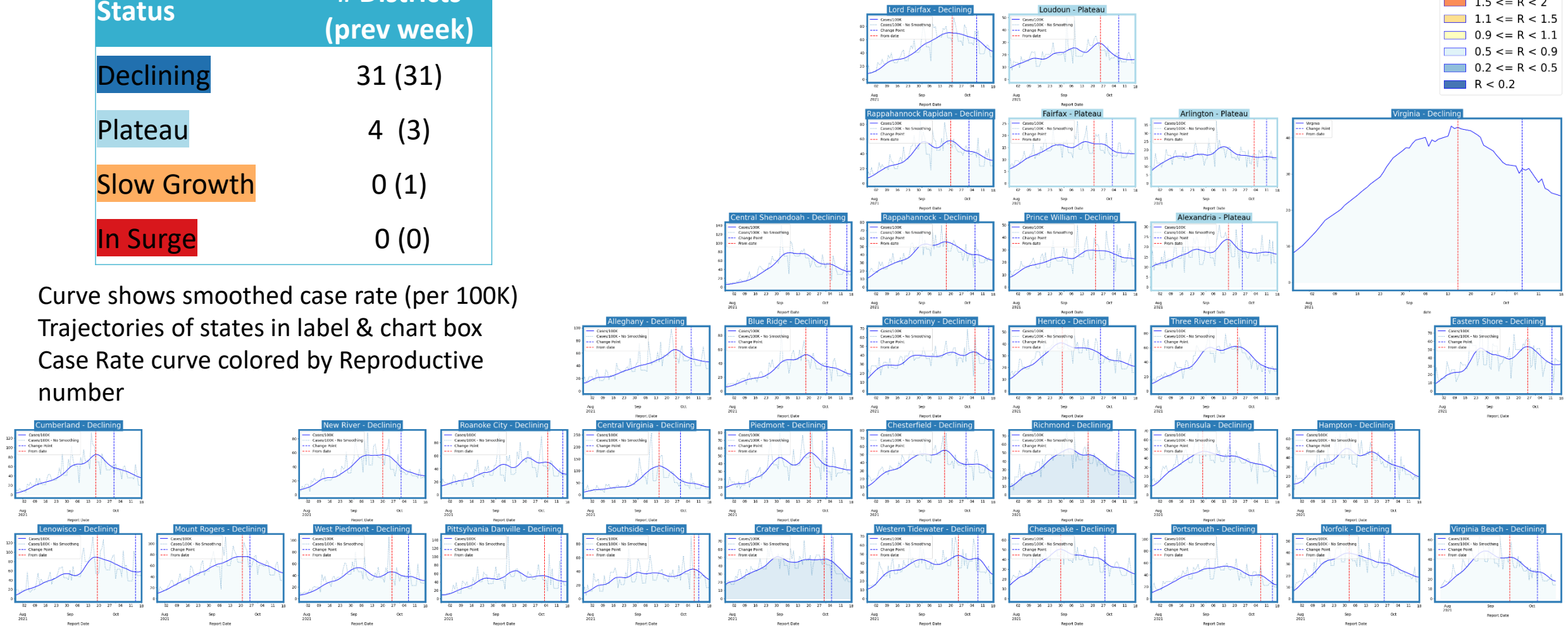
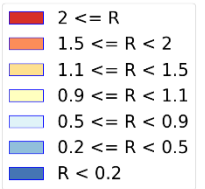


Trajectory	Description	Weekly Case Rate (per 100K) bounds	# Districts (prev week)
Declining	Sustained decreases following a recent peak	below -0.9	31 (31)
Plateau	Steady level with minimal trend up or down	above -0.9 and below 0.5	4 (3)
Slow Growth	Sustained growth not rapid enough to be considered a Surge	above 0.5 and below 2.5	0 (1)
In Surge	Currently experiencing sustained rapid and significant growth	2.5 or greater	0 (0)

District Trajectories – last 10 weeks

Status	# Districts (prev week)
Declining	31 (31)
Plateau	4 (3)
Slow Growth	0 (1)
In Surge	0 (0)

Curve shows smoothed case rate (per 100K)
Trajectories of states in label & chart box
Case Rate curve colored by Reproductive
number



Estimating Daily Reproductive Number – Redistributed gap

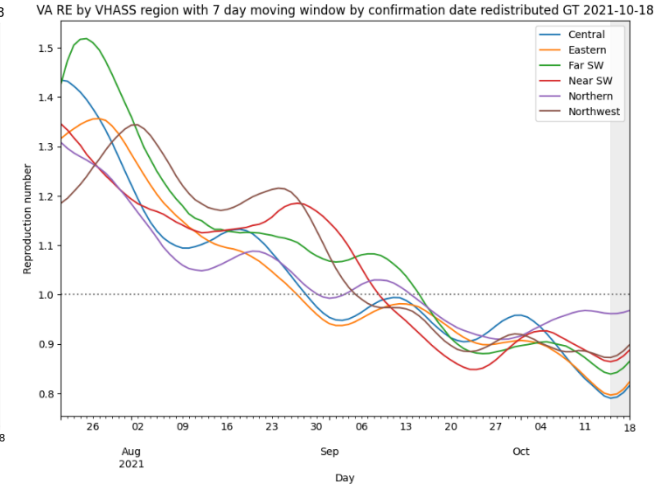
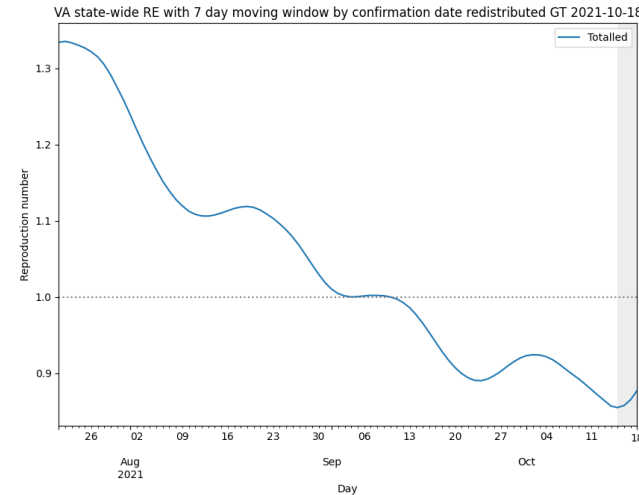
Oct 18th Estimates

Region	Date Confirmed R_e	Date Confirmed Diff Last Week
State-wide	0.879	-0.010
Central	0.818	-0.084
Eastern	0.824	-0.068
Far SW	0.869	0.011
Near SW	0.888	0.025
Northern	0.968	0.038
Northwest	0.893	0.080

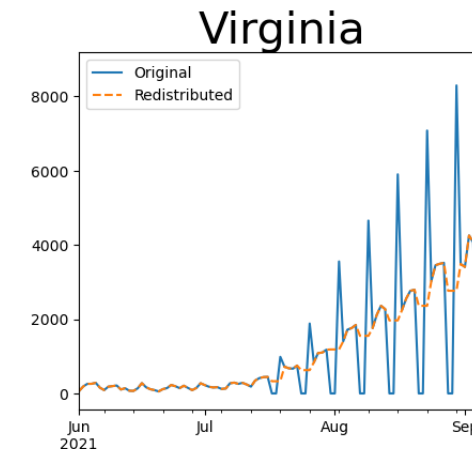
Methodology

- Wallinga-Teunis method (EpiEstim¹) for cases by confirmation date
- Serial interval: updated to discrete distribution from observations (mean=4.3, Flaxman et al, Nature 2020)
- Using Confirmation date since due to increasingly unstable estimates from onset date due to backfill

1. Anne Cori, Neil M. Ferguson, Christophe Fraser, Simon Cauchemez. A New Framework and Software to Estimate Time-Varying Reproduction Numbers During Epidemics. American Journal of Epidemiology, Volume 178, Issue 9, 1 November 2013, Pages 1505–1512, <https://doi.org/10.1093/aje/kwt133>



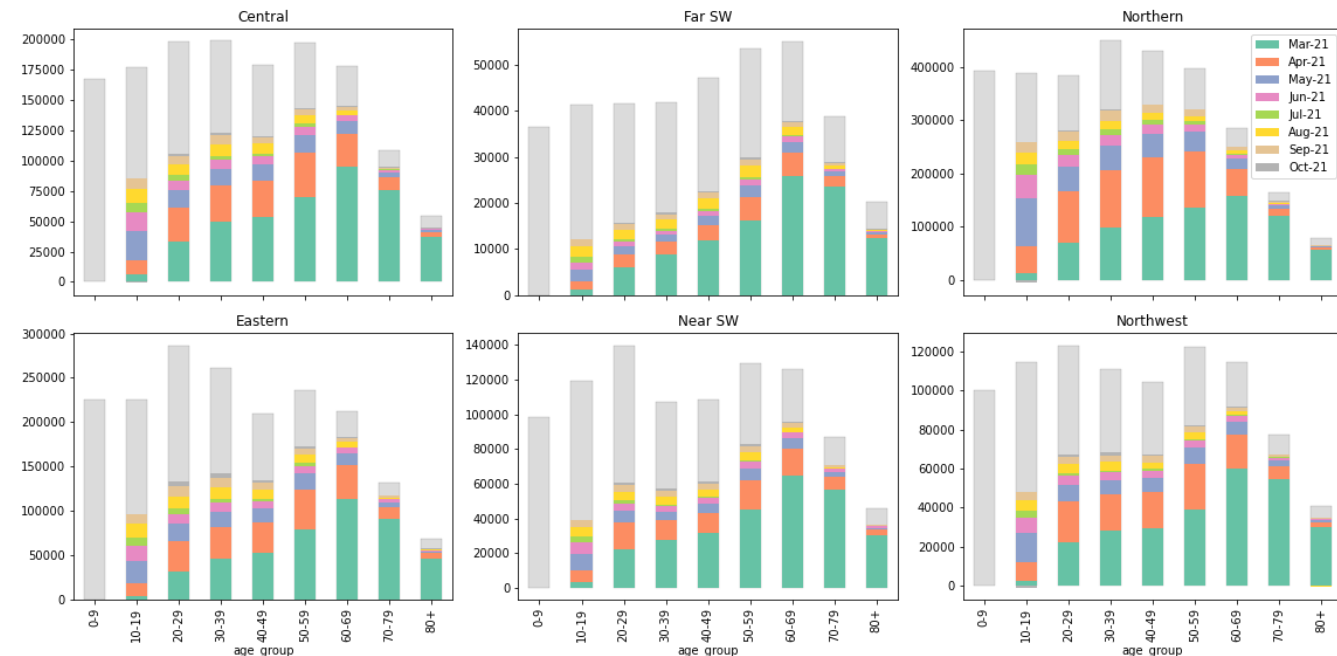
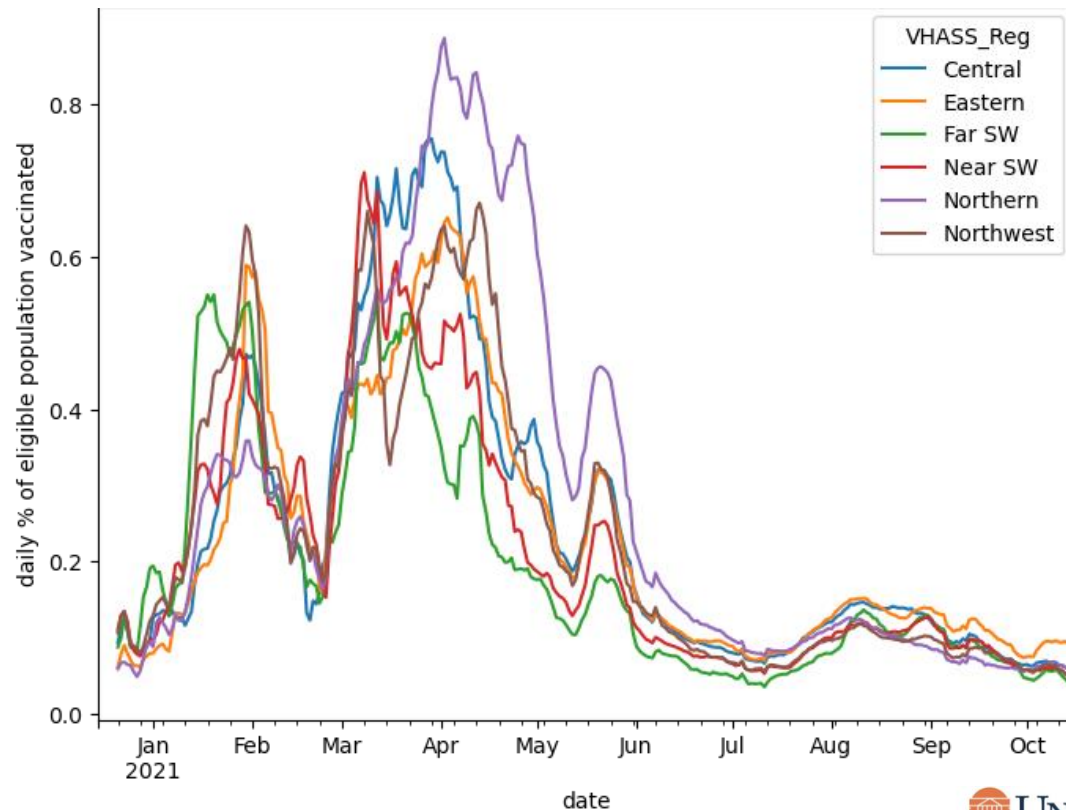
Skipping Weekend Reports & holidays biases estimates
Redistributed “big” report day to fill in gaps, and then estimate R from “smoothed” time series



Vaccination Administration Slow

Regional Vaccine courses initiated per day (% eligible):

- Proportion eligible for first dose of vaccines across regions (in the ~0.1% or 100 per 100K a day)
- Age-specific proportions of population vaccinated show recent progress in younger ages

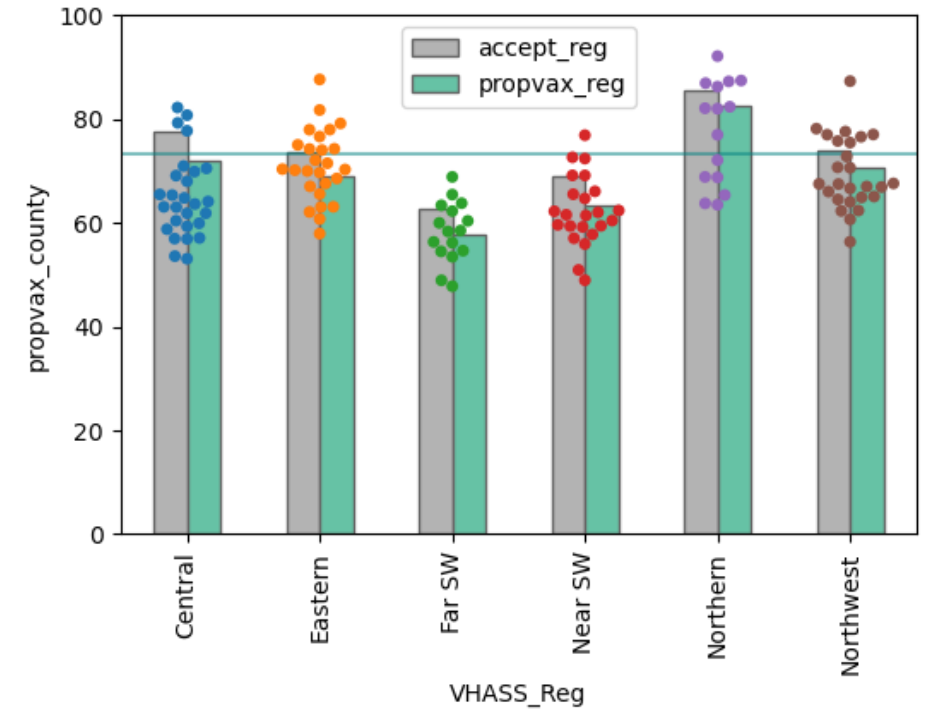


Vaccination Acceptance by Region

Corrections to surveys:

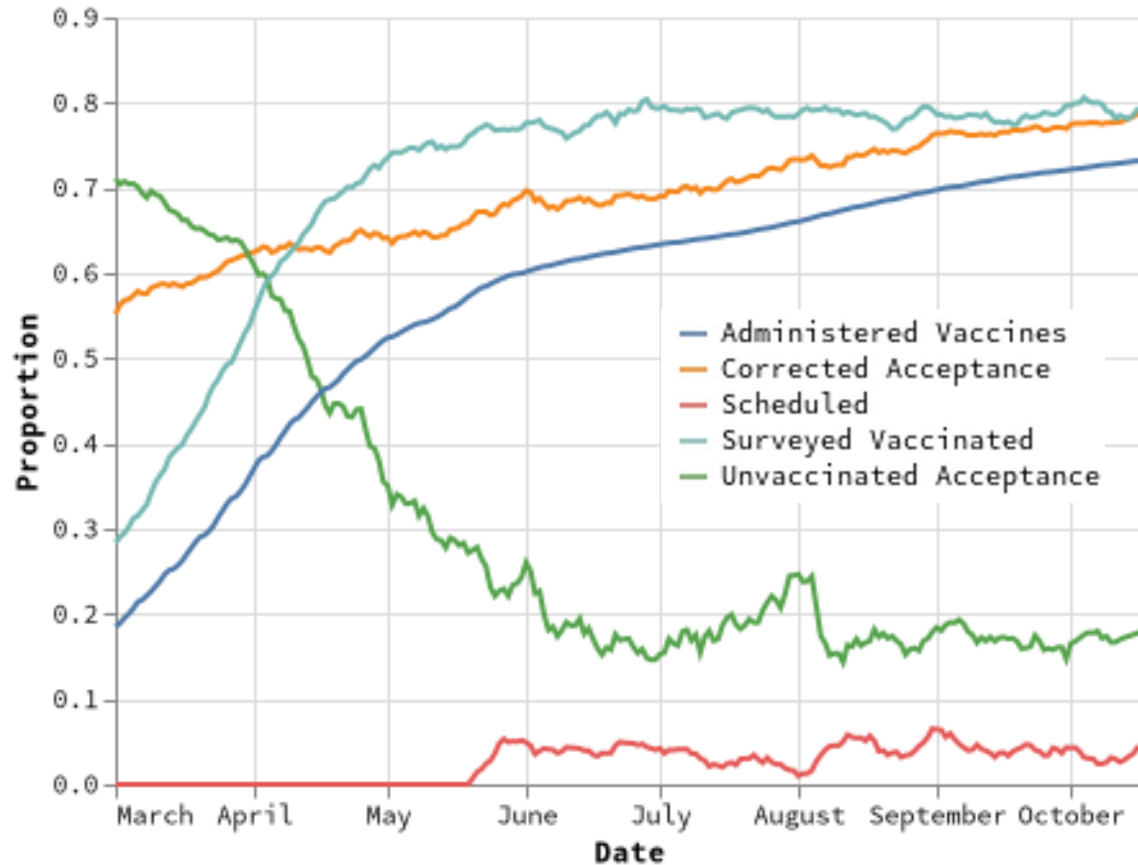
- Facebook administered survey is timely and broad, but biased by who accesses Facebook and answers the survey
- Correction approach:
 - Calculate an over-reporting fraction based on reported vaccinations compared to VDH administration data
 - Cross-validate coarse corrections against HPS survey at the state level and corrected in same manner

Region	COVIDcast accepting corrected	VDH proportion pop vaccinated
Central	79%	72%
Eastern	75%	69%
Far SW	68%	58%
Near SW	68%	63%
Northern	87%	83%
Northwest	76%	70%
Virginia	79%	73%



Grey Bar: Survey measured and corrected acceptance
Green Bar: Proportion of eligible population administered a vaccine
Dots: Proportion administered at least one dose for each county

Vaccine Acceptance Components over Time

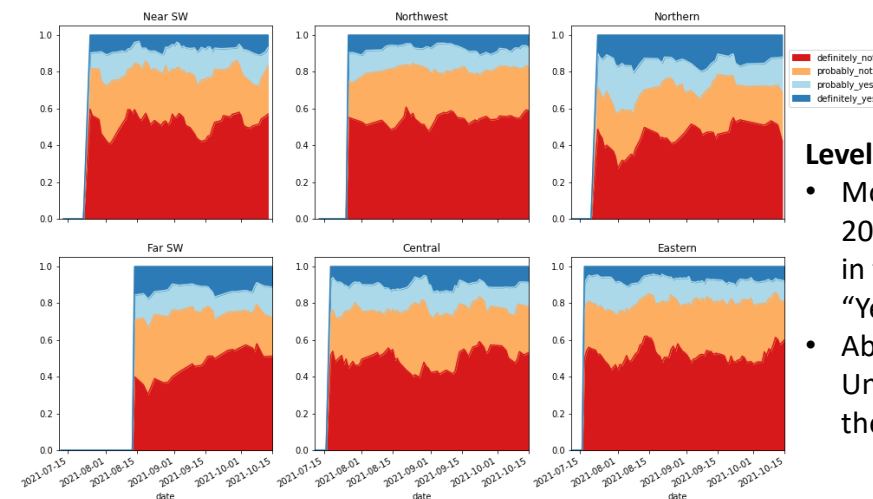


Vaccine Acceptance adjusted to include scheduled appointments

- Steady rise in acceptance over the past couple months
- Unvaccinated Acceptance shows ~20% of those who are unvaccinated are definitely or probably willing to be vaccinated
- Scheduled appointments for vaccination have increased through August but seem to be leveling off

Levels of Vaccine Willingness

Vaccine Readiness, Proportion of Non-Vaccinated



Levels of Acceptance in flux:

- Most regions are steady with 20-30% of unvaccinated still in the Definitely/Probably “Yes” categories.
- About 50% of the Unvaccinated seem to be in the “Definitely Not” category.

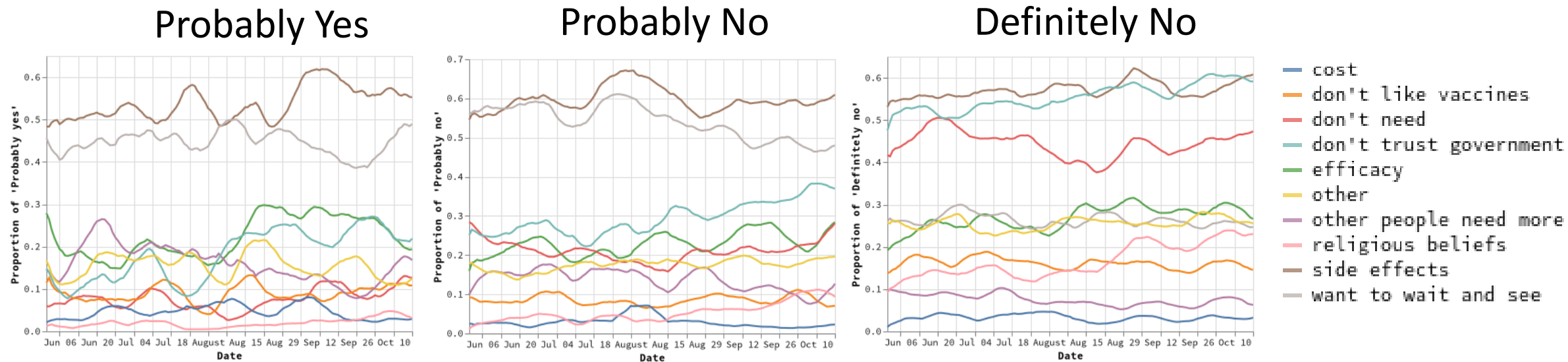
Data Source: <https://covidcast.cmu.edu>

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Reasons for Hesitancy by Likelihood to Accept



Reasons for Hesitancy vary across tiers of likelihood to accept the vaccine

- Probably Yes and Probably No most concerned about side effects & are waiting to see
- Definitely No are concerned about side effects but also don't think they need the vaccine and don't trust the government, though don't need is declining
- Most other reasons are below 30% within these tiers of likelihood

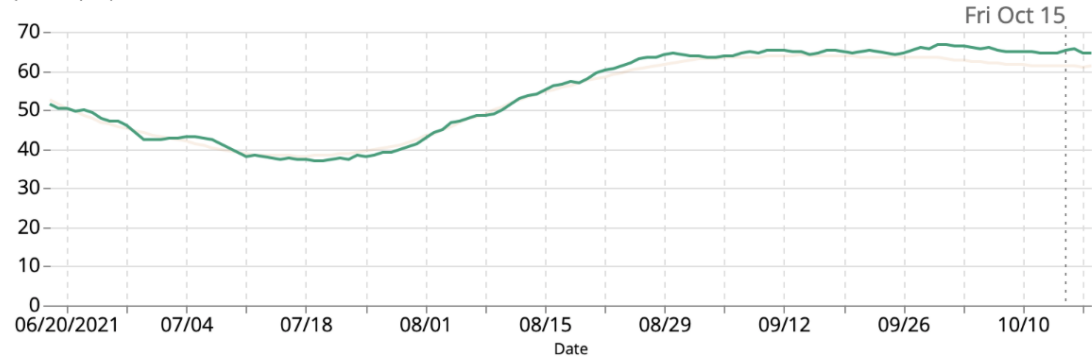
Mask Usage Stalls

Self-reported mask usage has plateaued out to ~65%, perhaps slight decline starting

- US and VA similar, though with considerable variation across counties and states
- Mask wearing remains lower amongst unvaccinated especially among least willing to be vaccinated

PEOPLE WEARING MASKS CHART

People Wearing Masks in Virginia
per 100 people

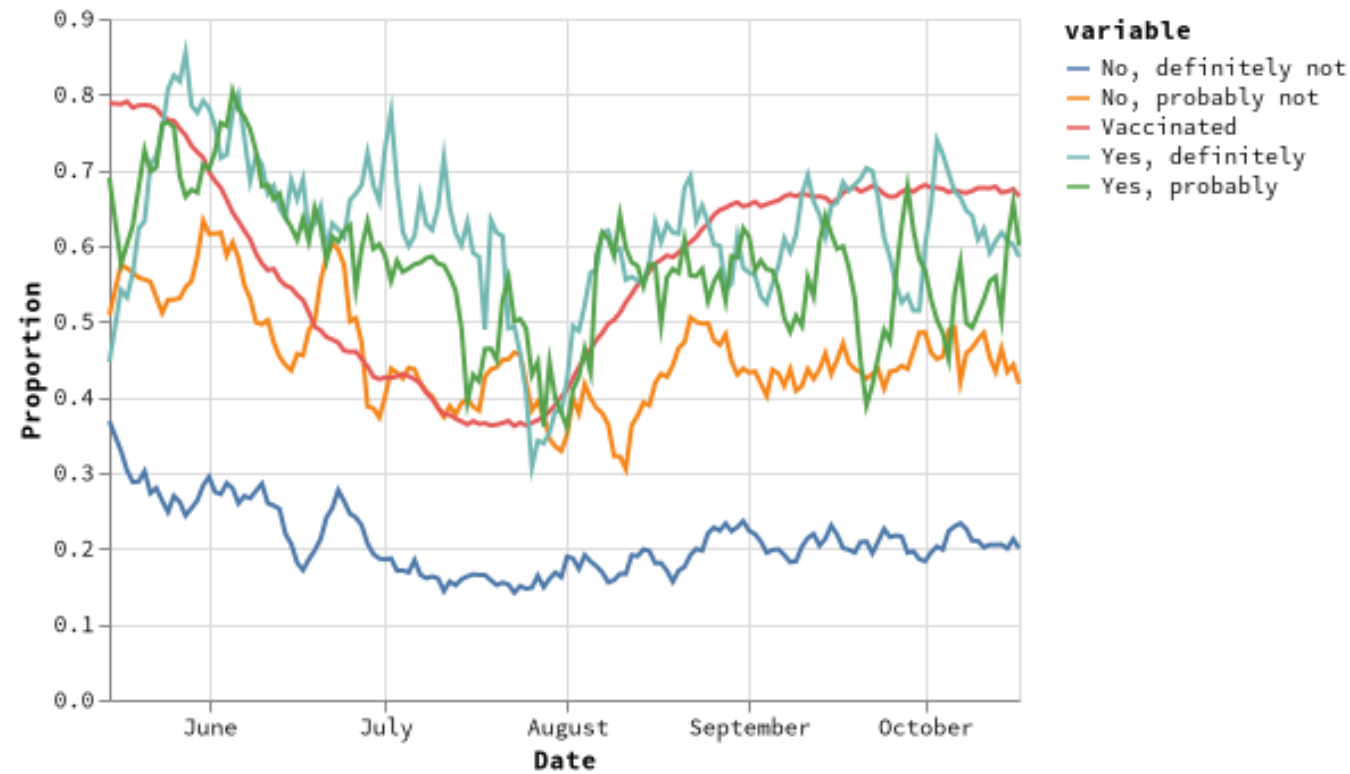


Delphi Group, delphi.cmu.edu/covidcast

☐ Rescale Y-axis ☐ Show All Dates

● Virginia
65.42% per 100

● United States
61.12% per 100



Data Source: <https://covidcast.cmu.edu>

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SARS-CoV2 Variants of Concern

Emerging new variants will alter the future trajectories of pandemic and have implications for future control

- Emerging variants can:
 - Increase transmissibility
 - Increase severity (more hospitalizations and/or deaths)
 - Limit immunity provided by prior infection and vaccinations
- Genomic surveillance remains very limited
 - Challenges ability to estimate impact in US to date and estimation of arrival and potential impact in future

	New WHO Name	Transmissibility	Immune Evasiveness	Vaccine Effectiveness [^]
Ancestral		—	—	✓
D614G		+	—	✓
B.1.1.7	Alpha	+++	—	✓
B.1.351	Beta	+	++++	✓
P.1	Gamma	++	++	✓
B.1.429	Epsilon	+	+	✓
B.1.526	Iota	+	+	✓
B.1.617.2	Delta	++++*	++ [#]	✓

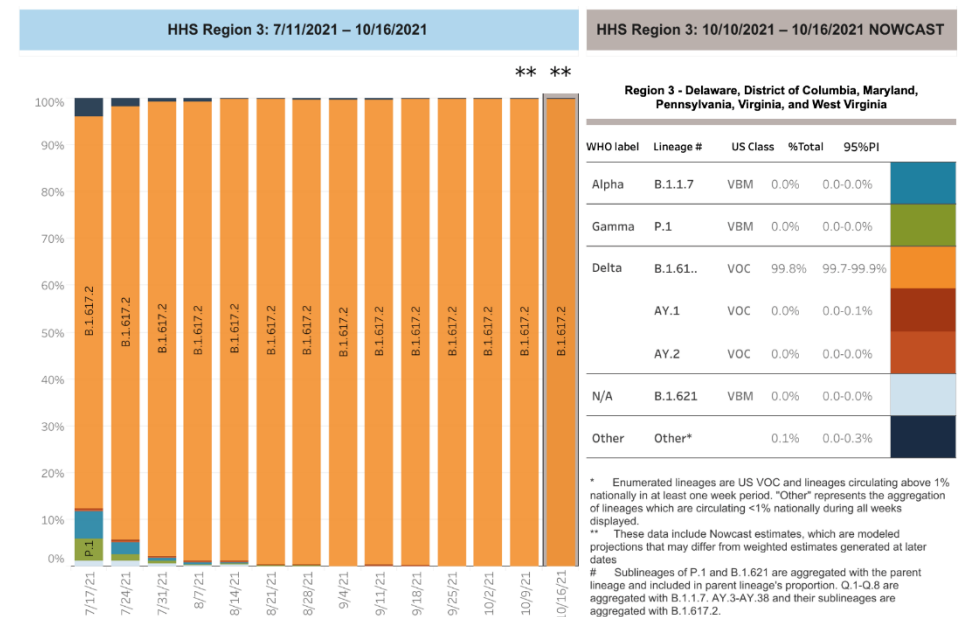
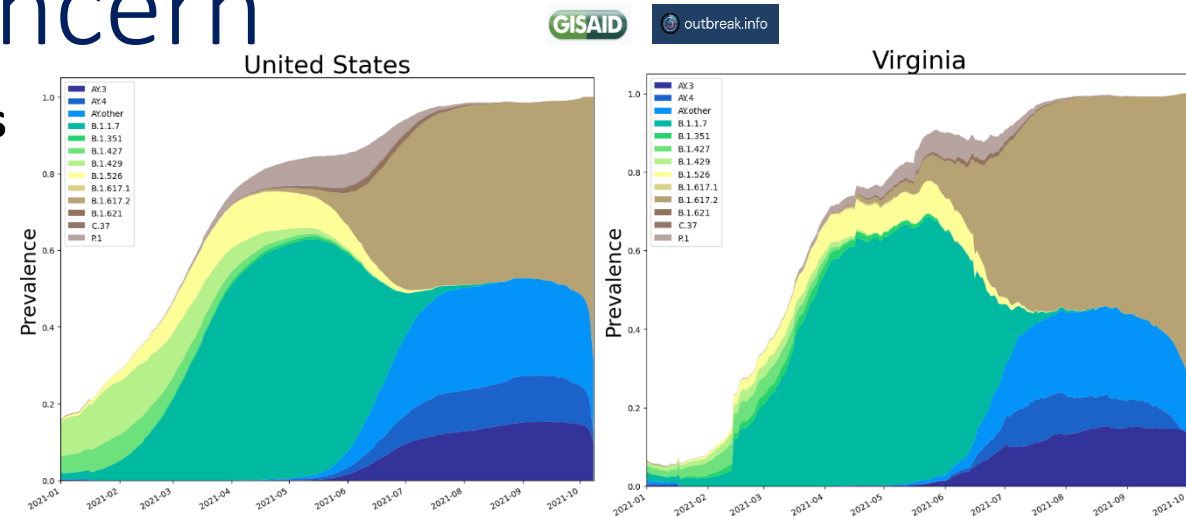
*Relative transmissibility to B.1.1.7 yet to be fully defined

[^]Effectiveness from real world evidence vs. severe illness, not all vaccines are effective vs all variants, and importance of 2-doses, especially for B.1.617.2 for which 1 dose of mRNA or AZ is only ~30% effective [#] May carry more immune escape than P.1, to be determined



World Health Organization

WHO and Eric Topol



* Enumerated lineages are US VOC and lineages circulating above 1% nationally in at least one week period. "Other" represents the aggregation of lineages which are circulating <1% nationally during all weeks displayed.

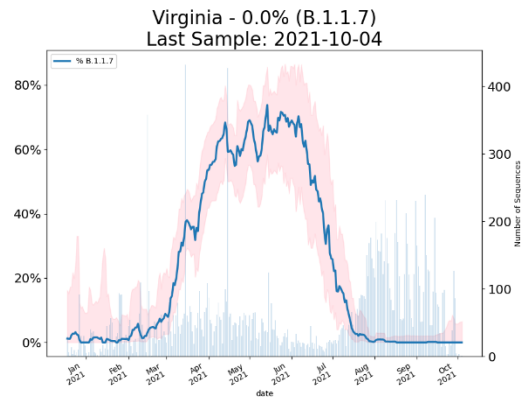
** These data include Nowcast estimates, which are modeled projections that may differ from weighted estimates generated at later dates.

[#] Sublineages of P.1 and B.1.621 are aggregated with the parent lineage and included in parent lineage's proportion. Q.1-Q.8 are aggregated with B.1.1.7, AY.3-AY.38 and their sublineages are aggregated with B.1.617.2.

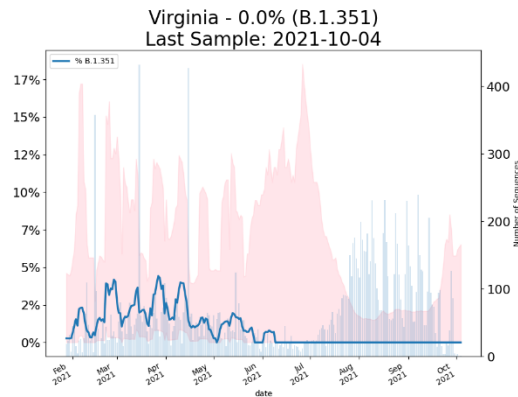
SARS-CoV2 Variants of Concern

Previous Variants

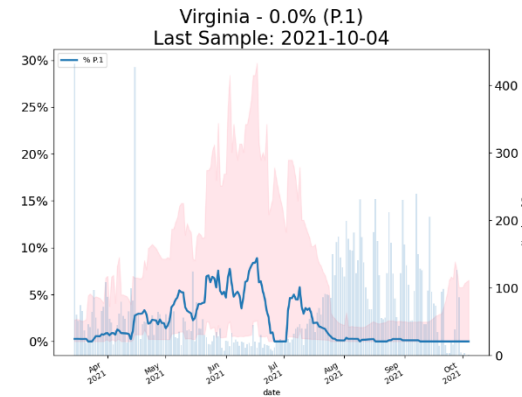
Alpha α - Lineage B.1.1.7



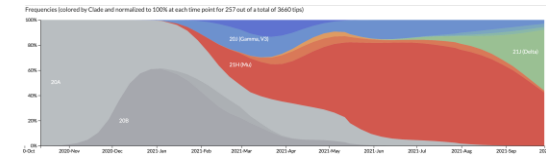
Beta β - Lineage B.1.351



Gamma γ - Lineage P.1

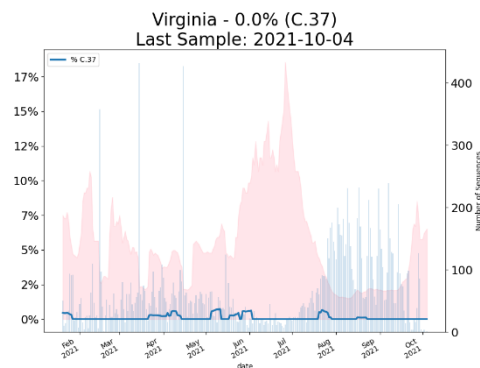


Colombia has highest proportion Mu and it is losing ground to Delta

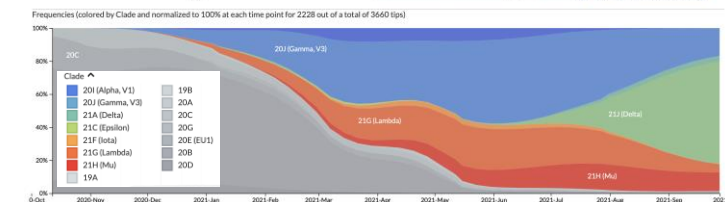
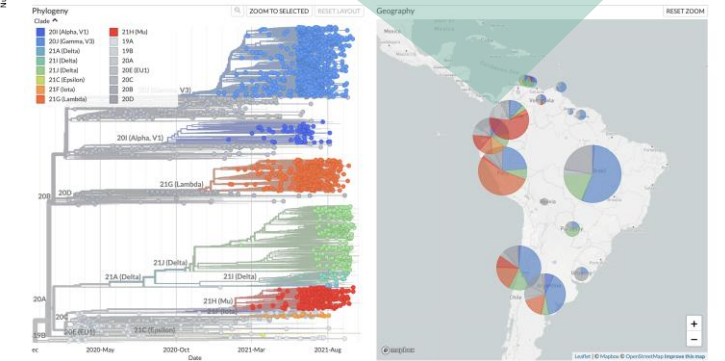
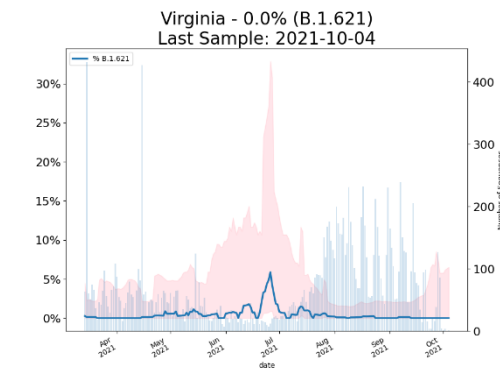


Emerging Variants

Lambda λ - Lineage C.37



Mu μ - Lineage B.1.621



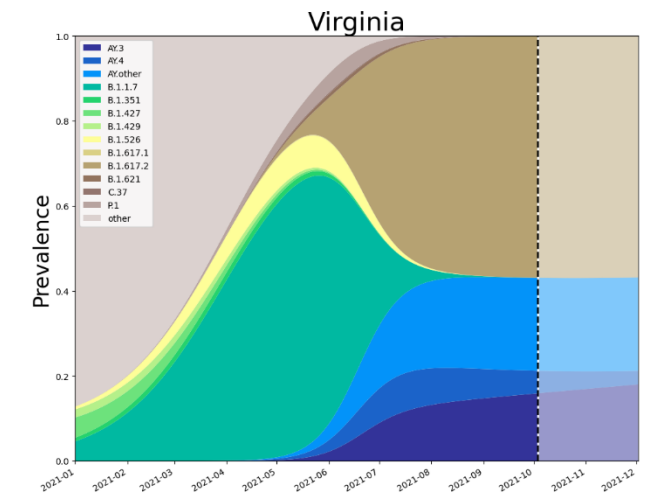
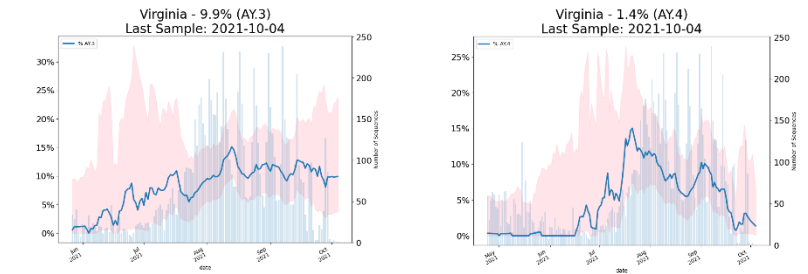
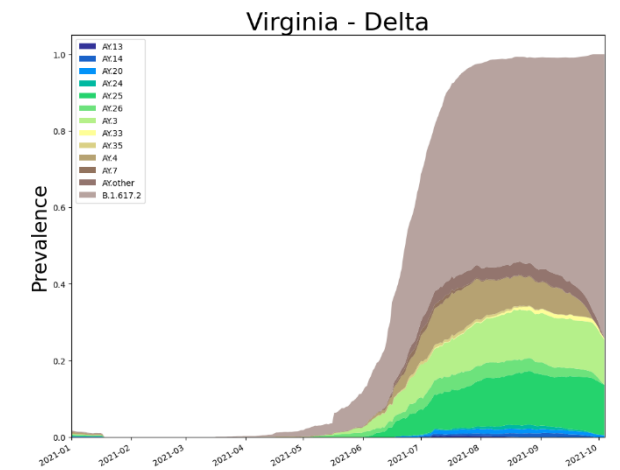
Delta continues to out compete Lambda and Mu in South America (over 60%, Lambda and Mu both below 10%)

[Trevor Bedford Tweet](#) & [Nextstrain Analysis](#)

SARS-CoV2 Variants of Concern

Delta δ - Lineage B.1.617.2 and related subvariants

- Delta plus $\delta+$ lineage which contains the K417N mutation is emerging as a sub-variant that is even more transmissible; declared a VoC in India
- Delta variant now dominates most of Europe and US
- CDC recommends resumption of mask wearing indoors due to reports of breakthrough infections of the vaccinated possibly being transmissible
- [Recent study from Mayo clinic](#) shows Delta reducing the efficacy of mRNA vaccines (Pfizer more so than Moderna) along with [other reports](#). [Israeli study](#) showed 64% efficacy against infection, however, a 3rd dose may [counteract this reduction](#)
- [Public Health Scotland study in Lancet](#) suggests Delta is 2x more likely to cause hospitalization than Alpha
- Subvariants AY.3 and AY.4 with some significant variability while there are limited genomes submitted, these subvariants are mainly clustered in the US, others mainly outside of US

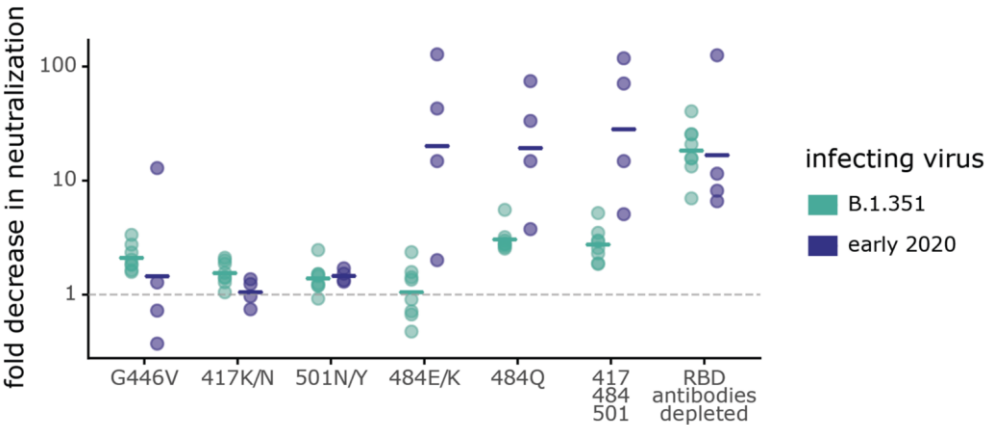


Current fits suggest stable mix of Delta & subvariants into the future

News, Variants & Vaccines

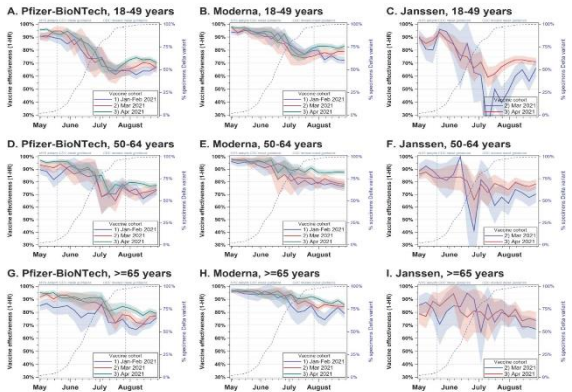
- 1. SARS-CoV-2 variants can elicit polyclonal antibodies with different immunodominance hierarchies focused on different parts of the virus. Likely to be a contributing factor in decreased effective antibody-based immunity.
- 2. Two doses of vaccine (Pfizer) were highly effective in preventing COVID-19 hospitalization among persons aged 12–18 years; highlight importance of vaccination to protect youths against severe COVID-19.
- 3. J&J vaccinated benefit from boosting with Pfizer, heterologous vaccination enhanced the quantity and breadth of both, Spike-specific humoral and cellular immunity in J&J vaccinated
- 4. Study from New York suggests that the Delta variant may be playing a role in the observed decreases in Vax effectiveness , adjusted VE for hospitalization still above 80% for all types and age groups (some better than others)

1

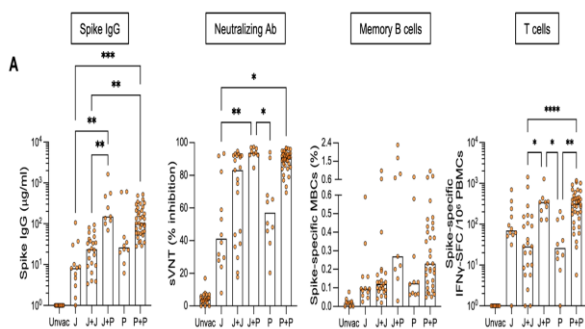


Researchers at the Fred Hutch institute characterized the specificities of polyclonal antibodies produced by humans infected with early 2020 isolates versus the B.1.351 variant of concern. B.1.351-elicited antibodies are more focused on the epitope spanning sites 443 to 452, and neutralization by these antibodies is notably less affected by mutations at residue 484. The results emphasize that antibodies generated by different strains can have significant and asymmetrical impact on the neutralizing capacity of convalescent sera <https://www.biorxiv.org/content/10.1101/2021.10.12.464114v1.full.pdf>

4



3



2

TABLE 3. Vaccine effectiveness* against COVID-19 among hospitalized patients aged 12–18 years, by vaccination status† — 19 pediatric hospitals, 16 states, § July–September 2021

Age group, yrs	No. vaccinated/Total (%)		Vaccine effectiveness, % (95% CI)
	Case-patients	Controls	
All	6/179 (3.4)	93/285 (32.6)	93 (83–97)
12–15	4/106 (3.8)	53/179 (29.6)	91 (74–97)
16–18	2/73 (2.7)	40/106 (37.7)	94 (78–99)

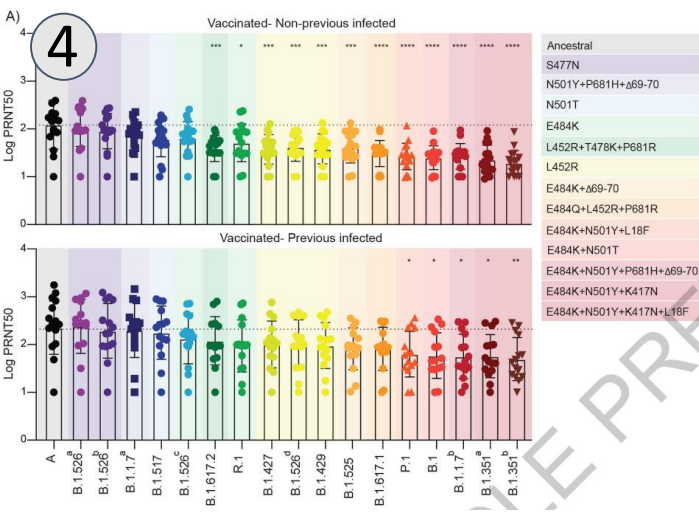
This CDC led study among 12-18 y/o used a test-negative design among 464 individuals judged the vaccine effectiveness of 2 doses of Pfizer-BioNTech vaccine against COVID-19 hospitalization during June–September 2021, was 93% (95% confidence interval = 83%–97%). [MMWR](#)

155,092 COVID-19 cases and 14,862 hospitalizations occurred. Estimated VE for cases declined contemporaneously across age, products, and time-cohorts, from high levels beginning May 1 (1.8% Delta variant prevalence), to a nadir around July 10 (85.3% Delta), with limited changes thereafter (>95% Delta). Decreases were greatest for Pfizer-BioNTech (–24.6%, –19.1%, –14.1% for 18–49, 50–64 years, and ≥65 years, respectively), and similar for Moderna (–18.0%, –11.6%, –9.0%, respectively) and Janssen (–19.2%, –10.8%, –10.9%, respectively). VE for hospitalization for adults 18–64 years was >86% across cohorts, without time trend. Among persons ≥65 years, VE declined from May to August for Pfizer-BioNTech (95.0% to 89.2%) and Moderna (97.2% to 94.1%). VE was lower for Janssen, without trend, ranging 85.5%–82.8%. <https://www.medrxiv.org/content/10.1101/2021.10.08.21264595v1>

Singapore led studied individuals either primed with Ad26.COV2.S only (n=13), or boosted with a homologous (Ad26.COV2.S, n=28) or heterologous (BNT162b2, n=14) second dose. In contrast, the impact of homologous boost was quantitatively minimal in Ad26.COV2.S vaccinated and Spike-specific antibodies and T cells were narrowly focused to the S1 region. <https://www.medrxiv.org/content/10.1101/2021.10.14.21264981v1.full.pdf>

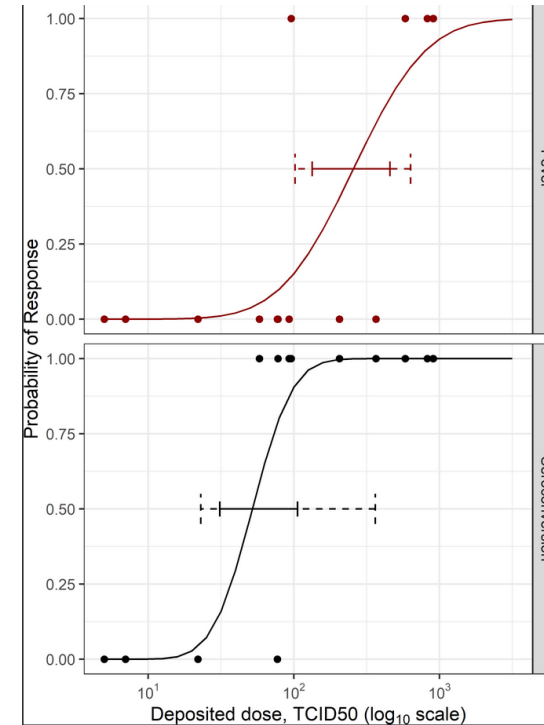
Variants & Vaccines

1. Partial or dense exposure to viral particles implicated in severity. These results reinforce the importance of public health measures that limit exposure dose, such as social distancing, masking, and increased ventilation.
2. Potentially largest study of a third dose of BNT162b2 vaccine in health-care workers shows high vaccine immunoreactivity. The median time between the first and third vaccine doses was 32.0 weeks. Israeli cohorts such as this one provide valuable data on robust immunity of large interval vaccination schedules.
3. Results demonstrate that the concept of vaccine bubbles is valuable, especially as we approach the holiday season.
4. "Plasma from previously infected vaccinated individuals displayed overall better neutralization capacity when compared to plasma from uninfected individuals that also received two vaccine doses, pointing to vaccine boosters as a relevant future strategy to alleviate the impact of emerging variants on antibody neutralizing activity."

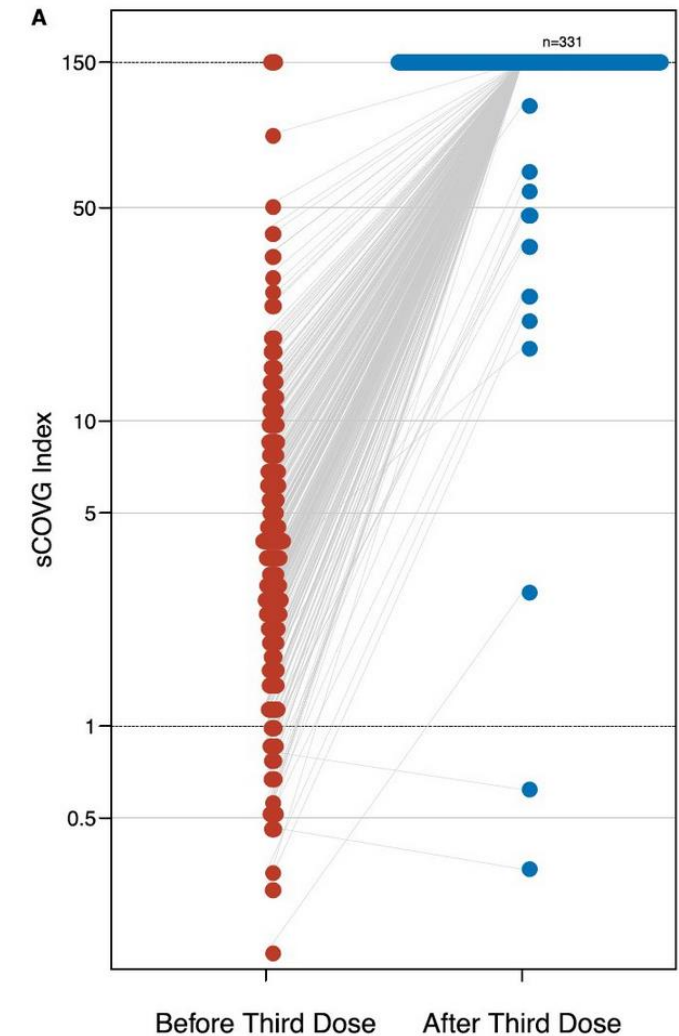
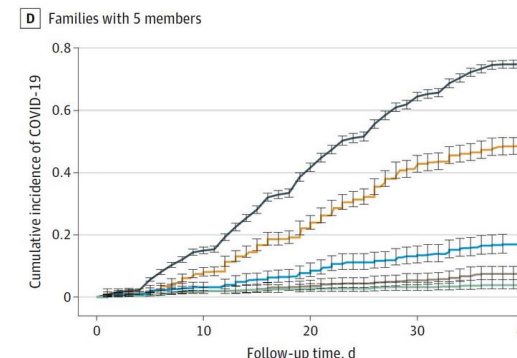
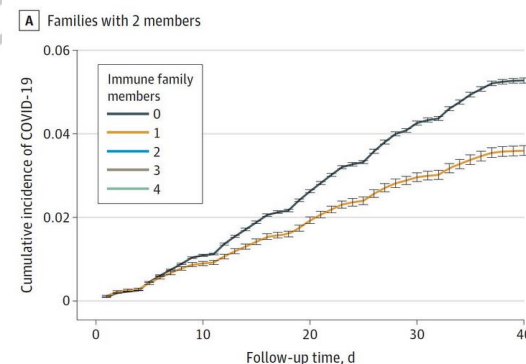


Recent Yale study demonstrates mRNA vaccines induce robust antibodies and T-cells; certain mutations increase immune escape; prior infection + 2 doses produces very high neutralizing concentrations against most variants
<https://www.nature.com/articles/s41586-021-04085-y> reference.pdf

- 1** National Biodefense Analysis and Countermeasures Center (NBACC) researchers conduct a study on 16 macaques and are the first to demonstrate that the probability of infection is dependent on the exposure dose of SARS-CoV-2 in a nonhuman primate model of inhalational COVID-19. The results demonstrate that the probability of seroconversion and fever are both dose-dependent, but that the median dose for seroconversion is significantly lower than that of fever, resulting in a group of animals that developed an immune response post-exposure but did not develop fever or other clinical signs of infection
<https://journals.plos.org/plospathogens/article?id=10.1371/journal.ppat.1009865>



- 3** Cohort study of 1,789,728 individuals from 814,806 families in Sweden, family members without immunity had a 45% to 97% lower risk of contracting COVID-19 as the number of immune family members increased.
<https://jamanetwork.com/journals/jamainternalmedicine/fullarticle/2785141>

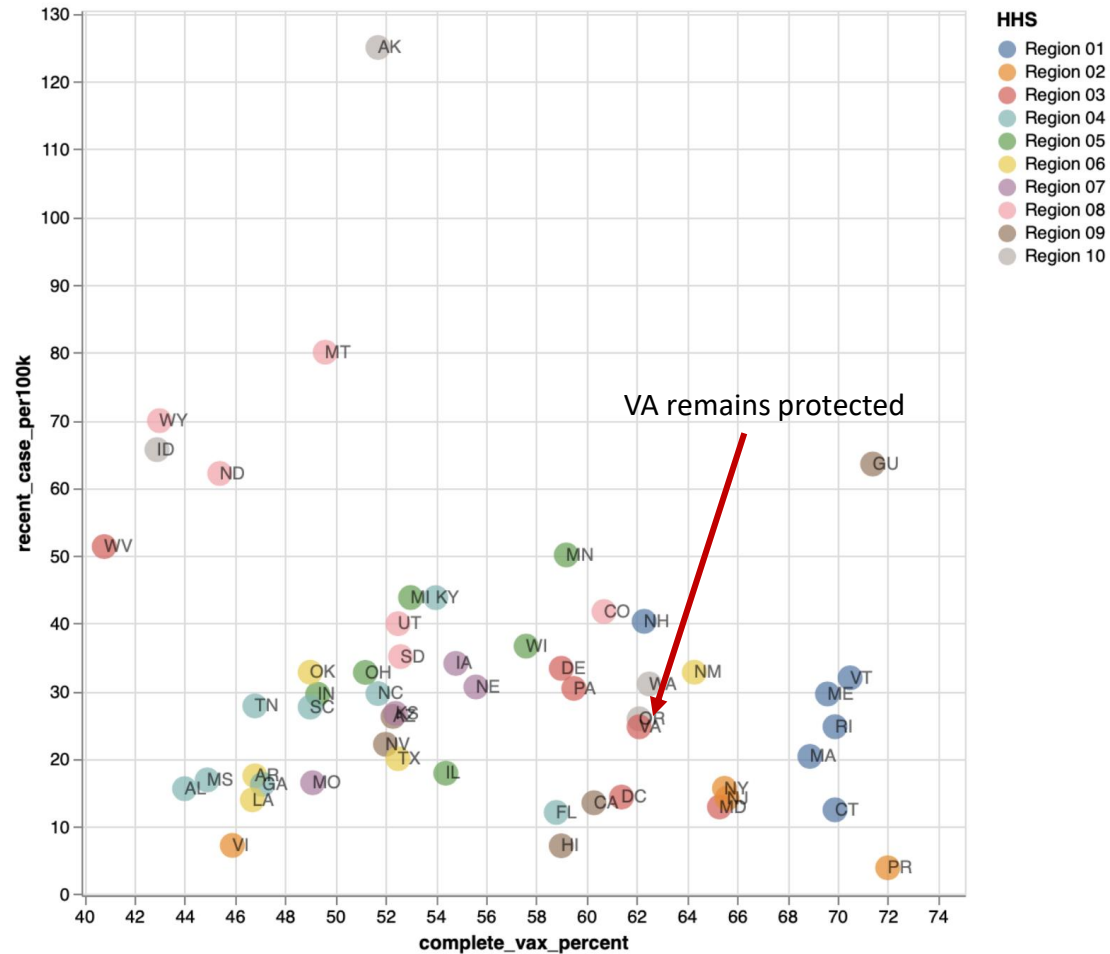


A new Israeli study demonstrates substantial IgG response of 346 healthcare workers (median age 67) induced by a 3rd shot/booster Pfizer vaccine. sCOVG index of serology assay has values up to 150 (upper limit of quantification), 1.00 or greater is considered positive for SARS-CoV-2 antibodies.
[https://www.thelancet.com/journals/lanmic/article/PIIS2666-5247\(21\)00272-X/fulltext](https://www.thelancet.com/journals/lanmic/article/PIIS2666-5247(21)00272-X/fulltext)

Recent Cases Correlate with Vax Coverage

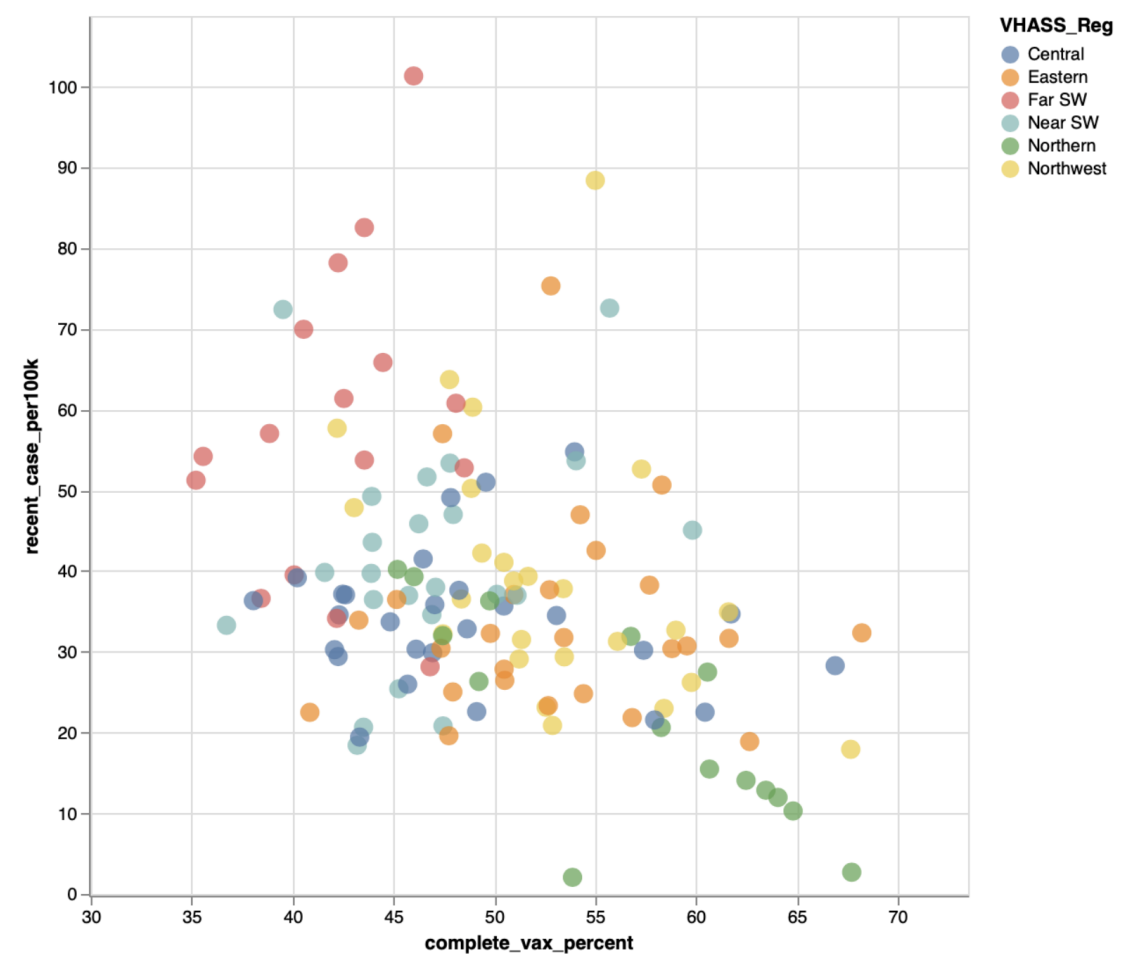
Mean cases per 100K vs. vaccine coverage

- States with lower vax coverage have had the worst case spikes



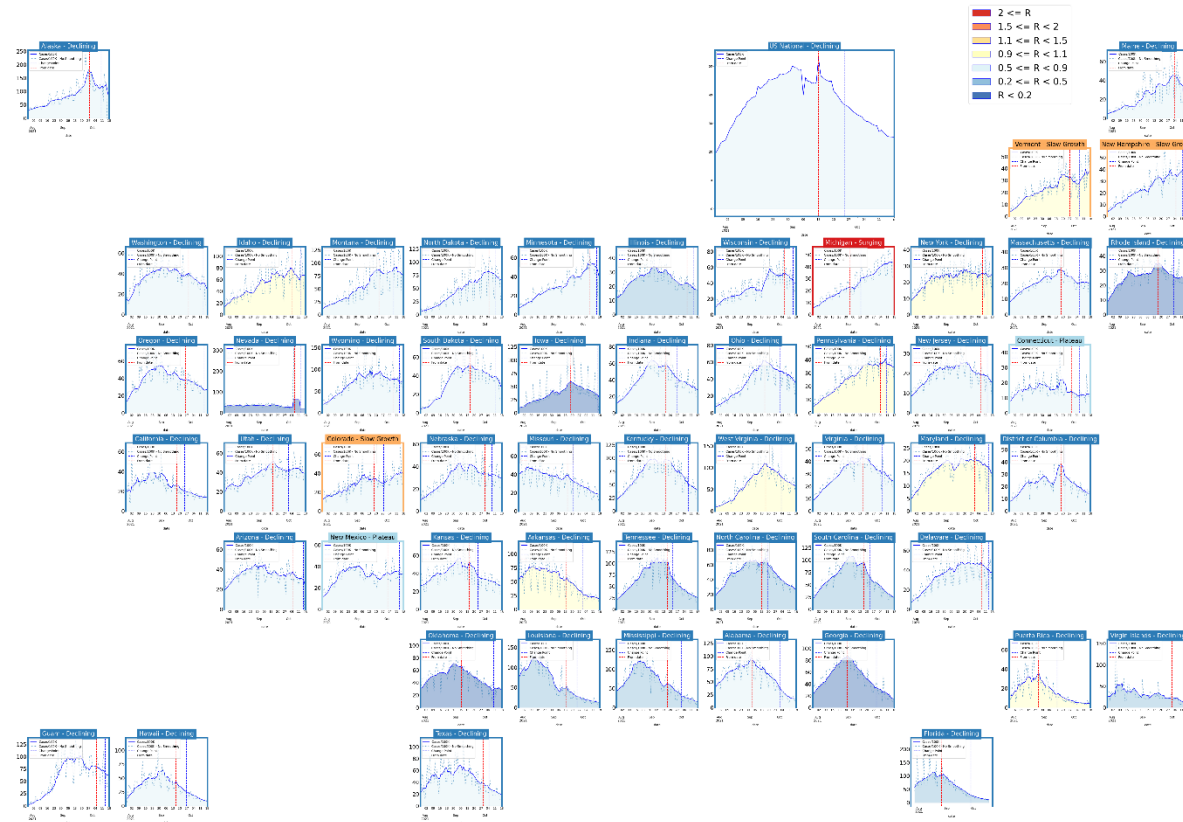
Virginia Counties

- Counties with higher vax coverage are maintaining lower case rates



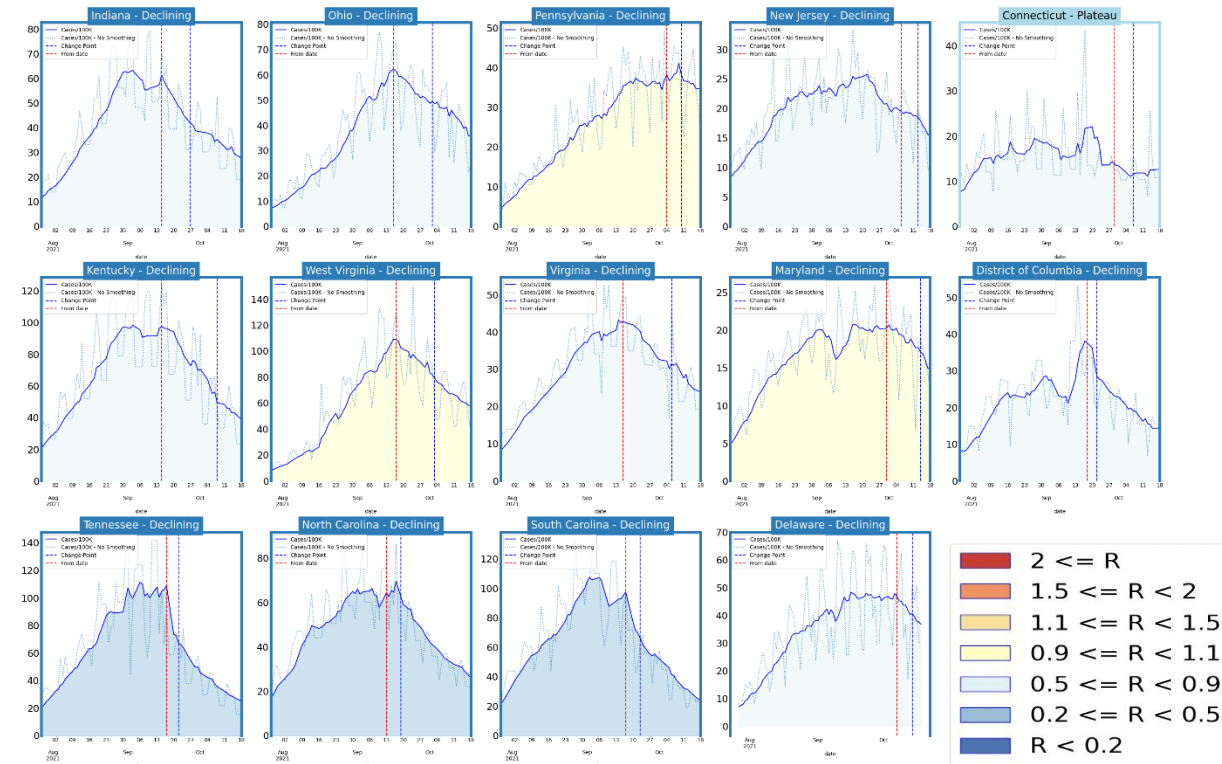
Other State Comparisons

Trajectories of States



- Most states continue to decline (48)
- Some states (4) remain in growth, or plateau (2)
- Case rates remain very high, but nationally rates have been in sustained decline

Virginia and her neighbors

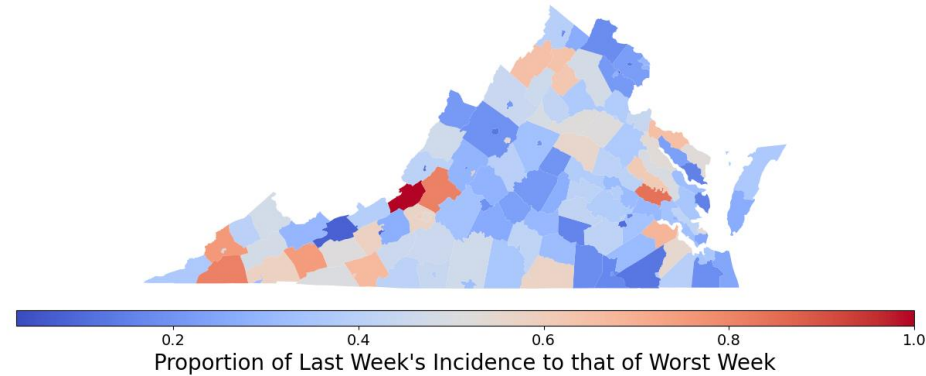


- Nearly all neighbors now in sustained decline in for several weeks or are exiting a prolonged plateau
- Case rates remain high

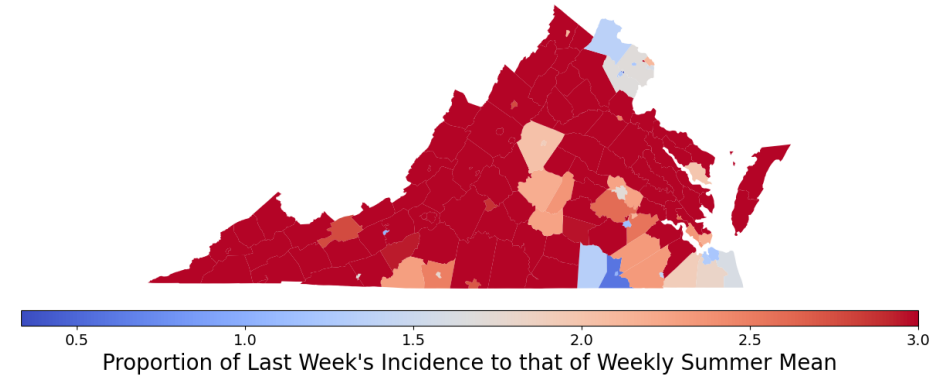
Last Week compared to the worst and the best

County level Case Rates (per 100K) proportion when comparing this most recent week to:

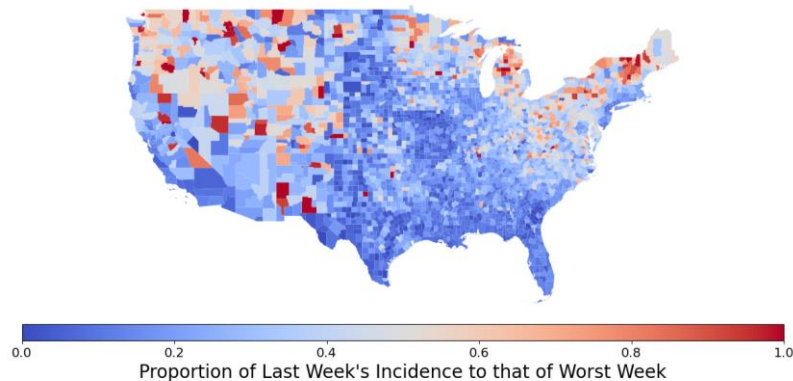
Worst Week of the Pandemic



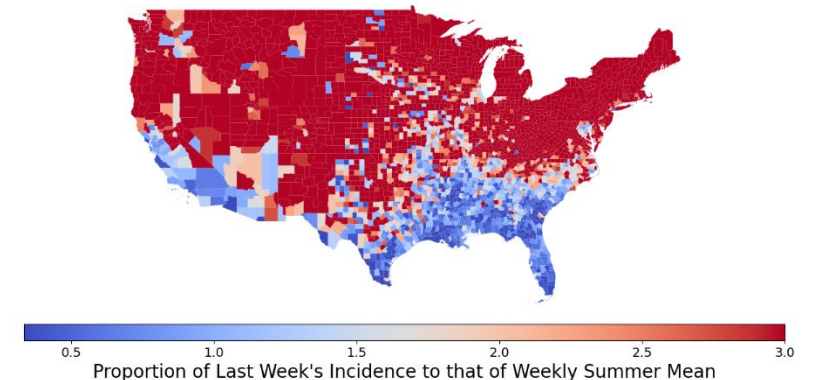
Summer 2020 mean



Recent Incidence Compared to Worst Week by County



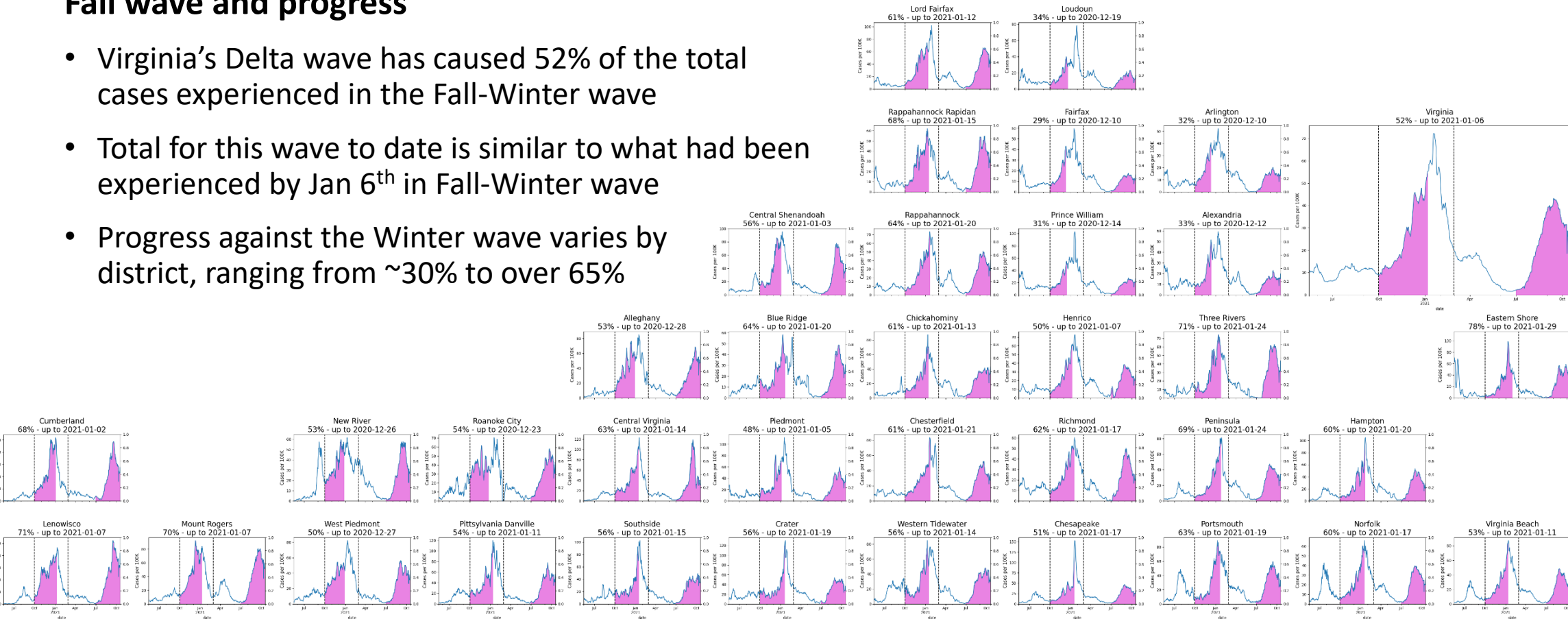
Recent Incidence Compared to Weekly Summer Mean by County
Mean: 84.17; Median: 3.64; IQR: 1.48-8.88



Delta Wave compared to Last Fall – Winter wave

Total cases in Delta wave compared to cases in Fall wave and progress

- Virginia's Delta wave has caused 52% of the total cases experienced in the Fall-Winter wave
- Total for this wave to date is similar to what had been experienced by Jan 6th in Fall-Winter wave
- Progress against the Winter wave varies by district, ranging from ~30% to over 65%



Zip code level weekly Case Rate (per 100K)

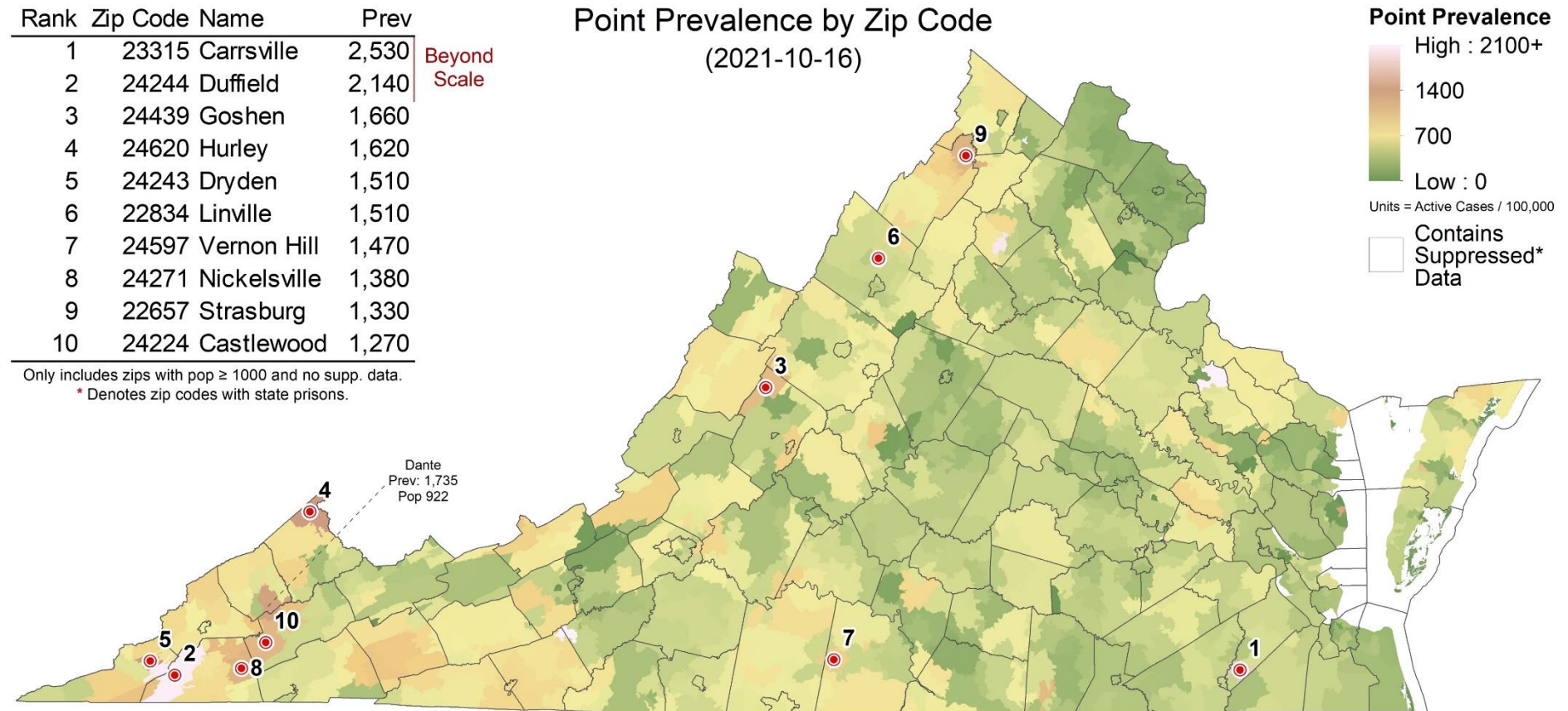
Case Rates in the last week by zip code

- Color scaled adjusted to accommodate the very high prevalence levels this week
- Clusters of high prevalence in Southwest and Northwest
- Some counts are low and suppressed to protect anonymity, those are shown in white

Rank	Zip Code	Name	Prev
1	23315	Carrsville	2,530
2	24244	Duffield	2,140
3	24439	Goshen	1,660
4	24620	Hurley	1,620
5	24243	Dryden	1,510
6	22834	Linville	1,510
7	24597	Vernon Hill	1,470
8	24271	Nickelsville	1,380
9	22657	Strasburg	1,330
10	24224	Castlewood	1,270

Only includes zips with pop ≥ 1000 and no supp. data.

* Denotes zip codes with state prisons.

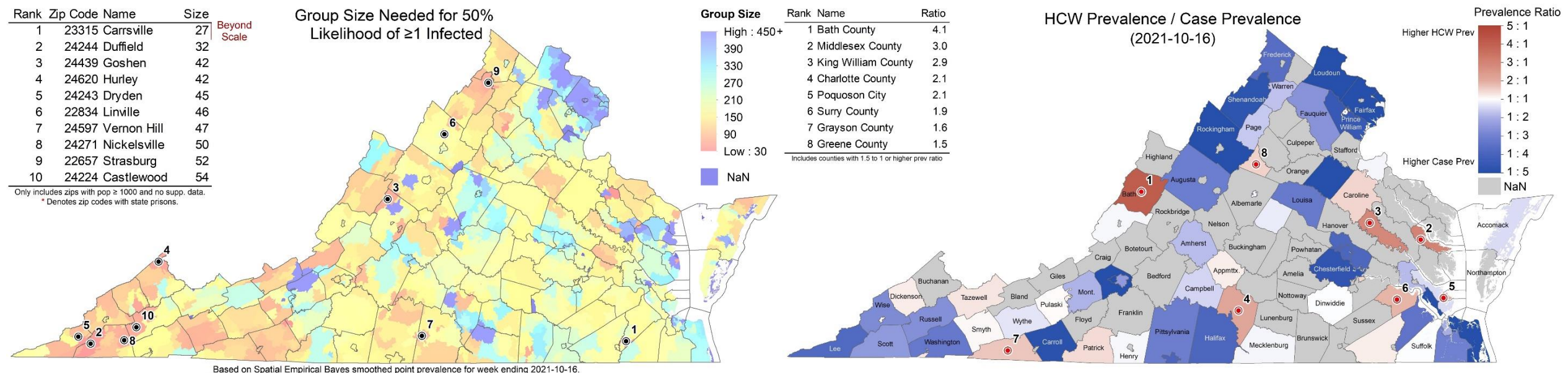


Based on Spatial Empirical Bayes smoothed point prevalence for week ending 2021-10-16.

Risk of Exposure by Group Size and HCW prevalence

Case Prevalence in the last week by zip code used to calculate risk of encountering someone infected in a gathering of randomly selected people (group size 25)

- **Group Size:** Assumes 2 undetected infections per confirmed case (ascertainment rate from recent seroprevalence survey), and shows minimum size of a group with a 50% chance an individual is infected by zip code (eg in a group of 27 in Carrsville, there is a 50% chance someone will be infected)
- **HCW ratio:** Case rate among health care workers (HCW) in the last week using patient facing health care workers as the denominator / general population's case prevalence



Current Hot-Spots

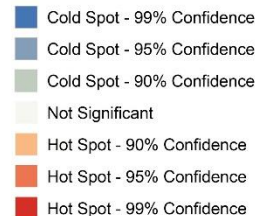
Case rates that are significantly different from neighboring areas or model projections

- **Spatial:** Getis-Ord Gi* based hot spots compare clusters of zip codes with weekly case prevalence higher than nearby zip codes to identify larger areas with statistically significant deviations
- **Temporal:** The weekly case rate (per 100K) projected last week compared to observed by county, which highlights temporal fluctuations that differ from the model's projections

Spatial Hotspots

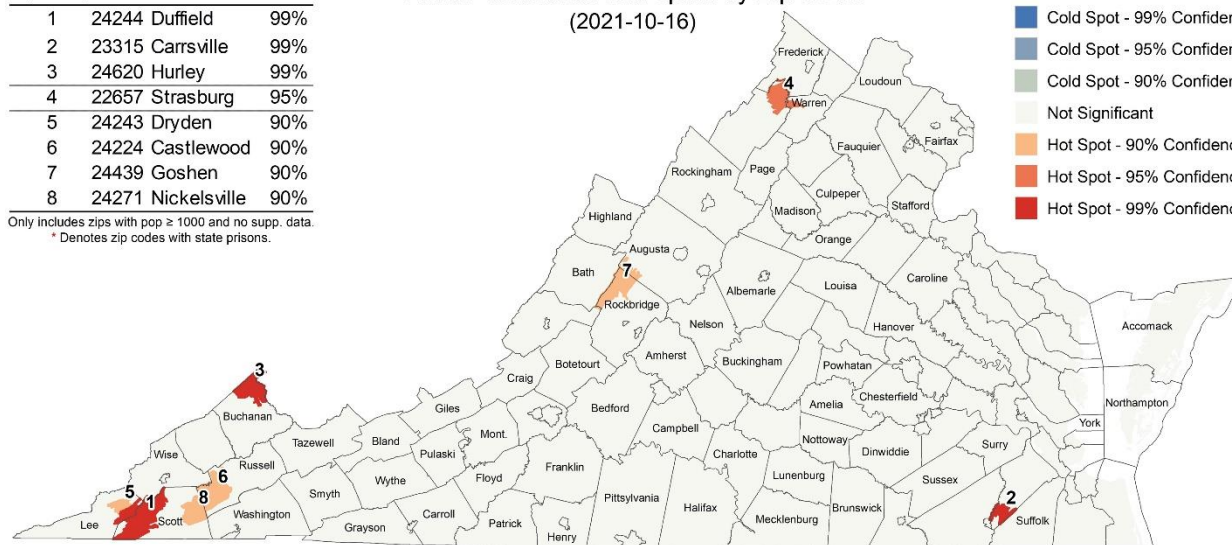
Point Prevalence Hot Spots by Zip Code
(2021-10-16)

Getis-Ord Gi* HotSpots



Spot	Zip Code	Name	Conf.
1	24244	Duffield	99%
2	23315	Carrsville	99%
3	24620	Hurley	99%
4	22657	Strasburg	95%
5	24243	Dryden	90%
6	24224	Castlewood	90%
7	24439	Goshen	90%
8	24271	Nickelsville	90%

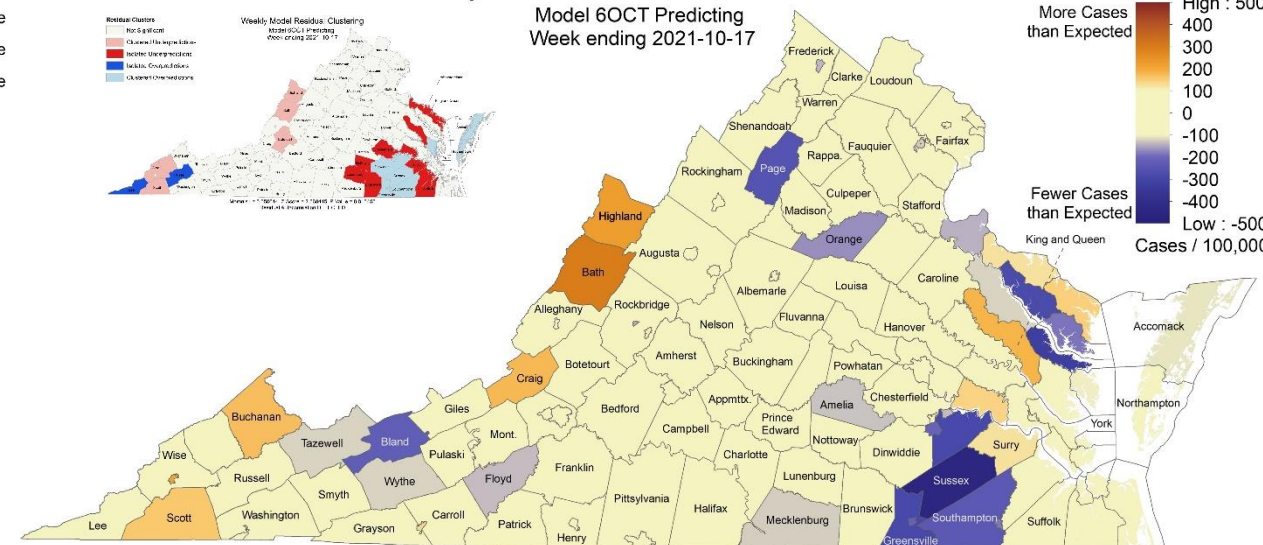
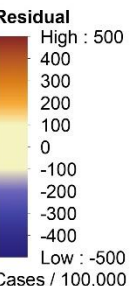
Only includes zips with pop > 1000 and no supp. data.
* Denotes zip codes with state prisons.



Based on Global Empirical Bayes smoothed point prevalence for week ending 2021-10-16.

Clustered Temporal Hotspots

Weekly Point Prevalence Model Residuals
Model 6OCT Predicting
Week ending 2021-10-17



Moran's I = 0.050614, Z-Score = 2.560415, P-Value = 0.010455
Residual Autocorrelation DETECTED

Model Update – Adaptive Fitting

Adaptive Fitting Approach

Each county fit precisely, with recent trends used for future projection

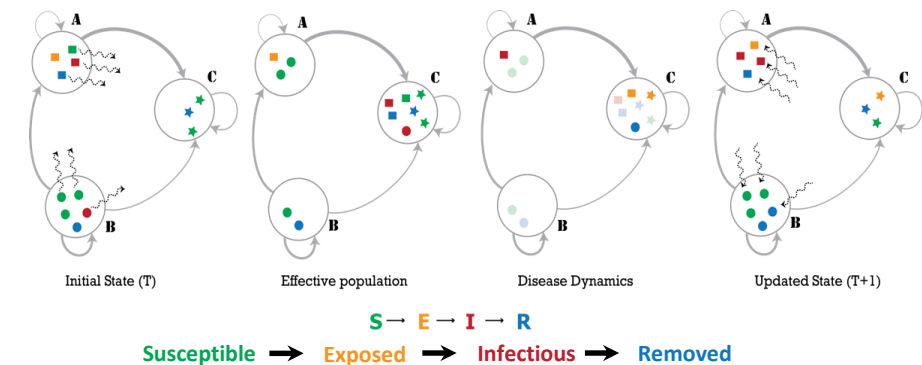
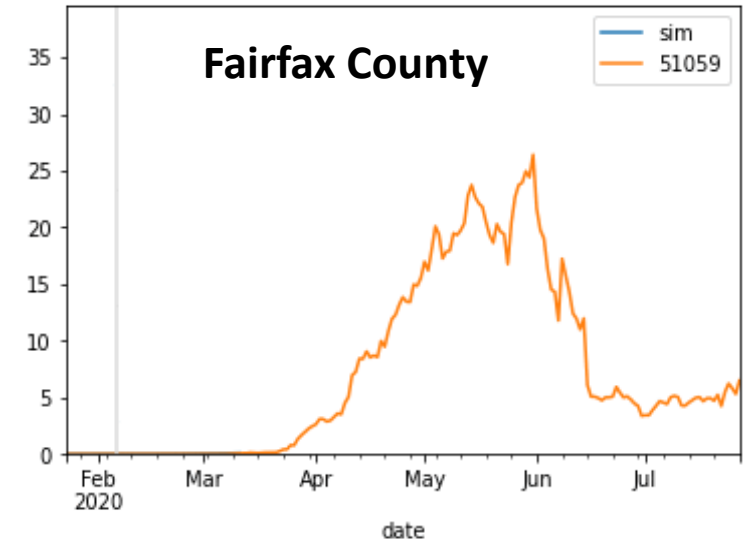
- Allows history to be precisely captured, and used to guide bounds on projections

Model: An alternative use of the same meta-population model, PatchSim

- Allows for future “what-if” Scenarios to be layered on top of calibrated model
- Eliminates connectivity between patches, to allow calibration to capture the increasingly unsynchronized epidemic

External Seeding: Steady low-level importation

- Widespread pandemic eliminates sensitivity to initial conditions
- Uses steady 1 case per 10M population per day external seeding



Using Ensemble Model to Guide Projections

Ensemble methodology that combines the Adaptive with machine learning and statistical models such as:

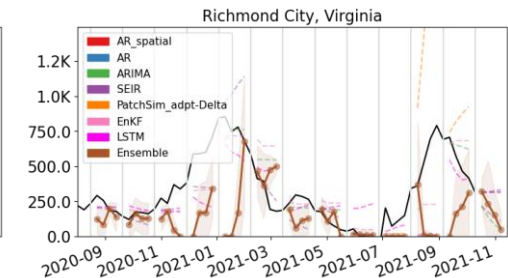
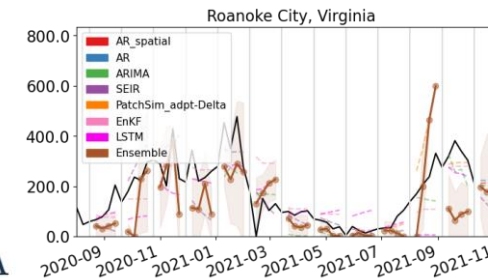
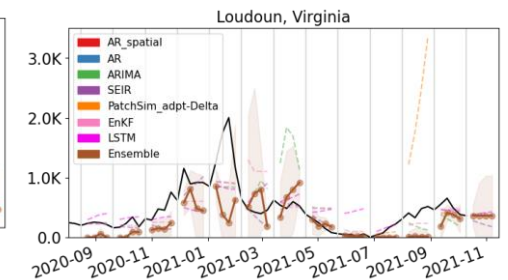
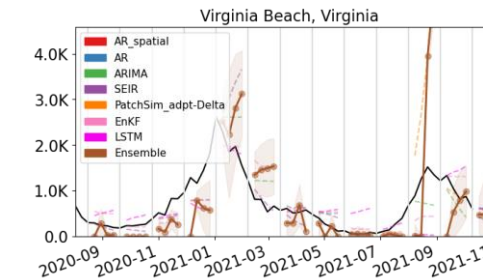
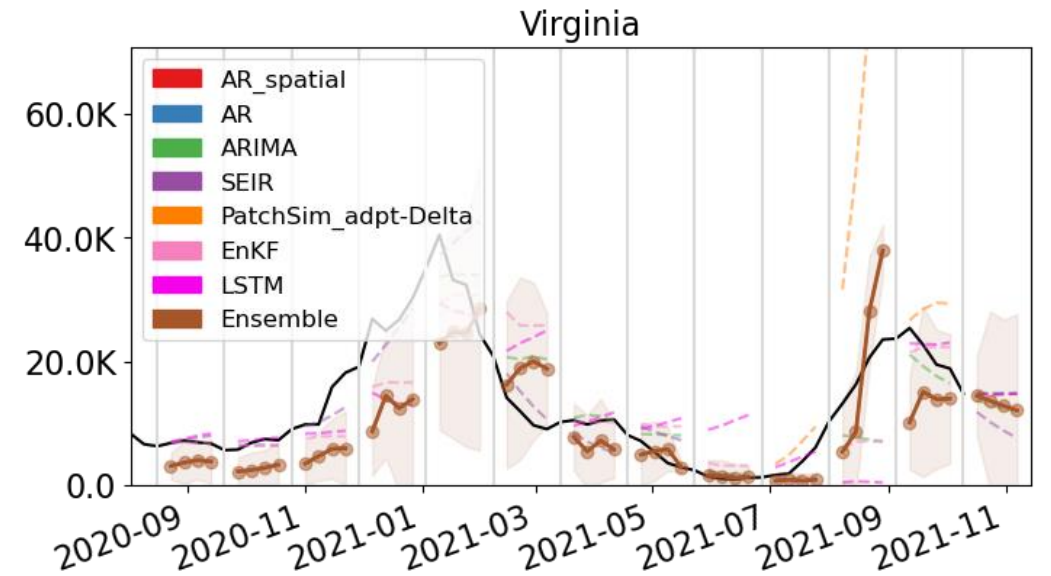
- Autoregressive (AR, ARIMA)
- Neural networks (LSTM)
- Kalman filtering (EnKF)

Weekly forecasts done at county level.

Models chosen because of their track record in disease forecasting and to increase diversity and robustness.

Ensemble forecast provides additional 'surveillance' for making scenario-based projections.

Also submitted to CDC Forecast Hub.



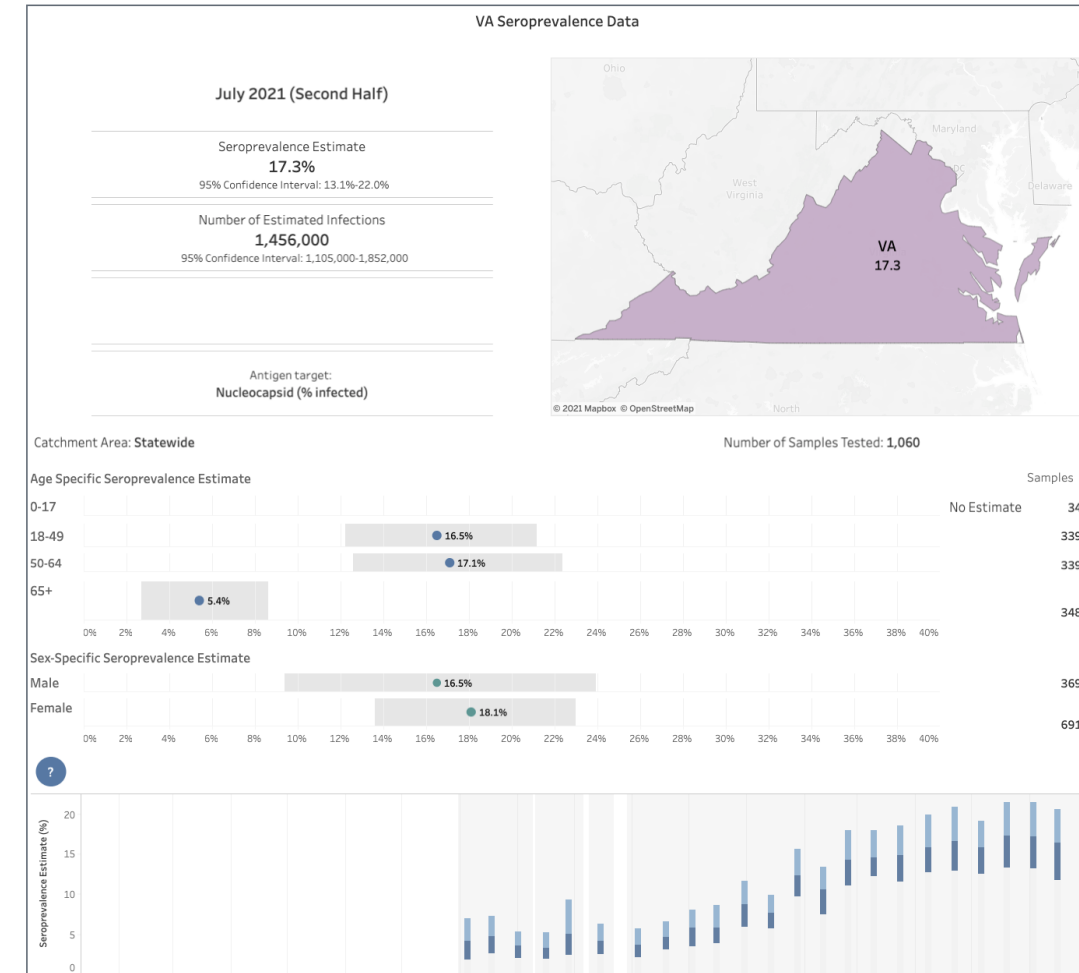
Seroprevalence updates to model design

Several seroprevalence studies provide better picture of how many actual infections have occurred

- CDC Nationwide Commercial Laboratory Seroprevalence Survey

These findings are equivalent to an ascertainment ratio of ~2x in the future, with bounds of (1.3x to 3x)


- Thus for 2x there are 2 total infections in the population for every confirmed case recently
- This measure now fully tracks the estimated ascertainment over time
- Uncertainty design has been shifted to these bounds (previously higher ascertainments as was consistent earlier in the pandemic were being used)



<https://covid.cdc.gov/covid-data-tracker/#national-lab>

Calibration Approach

- **Data:**
 - County level case counts by date of onset (from VDH)
 - Confirmed cases for model fitting
- **Calibration:** fit model to observed data and ensemble's forecast
 - Tune transmissibility across ranges of:
 - Duration of incubation (5-9 days), infectiousness (3-7 days)
 - Undocumented case rate (1x to 7x) guided by seroprevalence studies
 - Detection delay: exposure to confirmation (4-12 days)
 - Approach captures uncertainty, but allows model to precisely track the full trajectory of the outbreak
- **Project:** future cases and outcomes generated using the collection of fit models run into the future
 - **Mean trend from last 7 days of observed cases and first week of ensemble's forecast used**
 - Outliers removed based on variances in the previous 3 weeks
 - 2 week interpolation to smooth transitions in rapidly changing trajectories
- **Outcomes:** Data driven by shift and ratio that has least error in last month of observations
 - Hospitalizations: 3 days from confirmation, 6.8% of cases hospitalized
 - Deaths: 11 days from confirmation, 1.45% of cases die



COVID-19 in Virginia:

Dashboard Updated: 10/19/2021

Data entered by 5:00 PM the prior day.

Cases, Hospitalizations and Deaths

<div>Total Cases*</div> <div>909,499</div> <div>(New Cases: 1,617)^</div>	<div>Total Hospitalizations**</div> <div>38,041</div>	<div>Total Deaths</div> <div>13,538</div>
<div>Confirmed†</div> <div>676,927</div>	<div>Probable†</div> <div>232,572</div>	<div>Confirmed†</div> <div>11,385</div>
<div>Confirmed†</div> <div>35,889</div>	<div>Probable†</div> <div>2,152</div>	<div>Probable†</div> <div>2,153</div>

* Includes both people with a positive test (Confirmed), and symptomatic with a known exposure to COVID-19 (Probable).

** Hospitalization of a case is captured at the time VDH performs case investigation. This underrepresents the total number of hospitalizations in Virginia.

^New cases represent the number of confirmed and probable cases reported to VDH in the past 24 hours.

† VDH adopted the updated CDC COVID-19 2021 Surveillance Case Definition on September 1, 2021 which is found here: --

<https://ndc.services.cdc.gov/case-definitions/coronavirus-disease-2019-2021/>

Outbreaks

<div>Total Outbreaks*</div> <div>4,797</div>	<div>Outbreak Associated Cases</div> <div>87,688</div>
--	--

* At least two (2) lab confirmed cases are required to classify an outbreak.

Testing (PCR Only)

<div>Testing Encounters PCR Only*</div> <div>9,718,438</div>	<div>Current 7-Day Positivity Rate PCR Only**</div> <div>6.8%</div>
--	---

* PCR* refers to "Reverse transcriptase polymerase chain reaction laboratory testing."

** Lab reports may not have been received yet. Percent positivity is not calculated for days with incomplete data.

Multisystem Inflammatory Syndrome in Children

<div>Total Cases*</div> <div>96</div>	<div>Total Deaths</div> <div>0</div>
---------------------------------------	--------------------------------------

*Cases defined by CDC HAN case definition: <https://emergency.cdc.gov/han/2020/han00432.asp>

Accessed 9:30am October 20, 2021
<https://www.vdh.virginia.gov/coronavirus/>

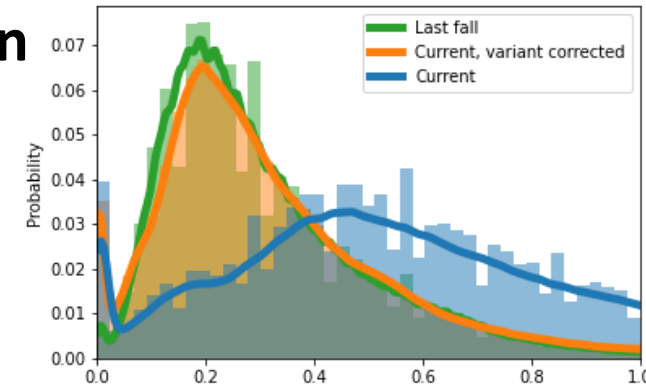
Scenarios – Transmission Conditions

- Variety of factors continue to drive transmission rates
 - Seasonal impact of weather patterns, travel and gatherings, fatigue and premature relaxation of infection control practices
- **Waning Immunity:** Mean of one year protection (rate of 0.0027) similar to [Pfizer study](#)
- **Projection Scenarios:**
 - **Adaptive:** Control remains as is currently experienced into the future with assumption that Delta remains as the majority strain
 - **Adaptive-FallWinter2020:** Starting this week the core drivers of transmission from Sept 2020 – Feb 2021 are coarsely replayed but boosted to account for Delta's increased transmissibility
 - **Adaptive-Surge Control:** Starting in one week behaviors and mitigation efforts ramp up over a 2-week period culminating in a 25% reduction in transmission

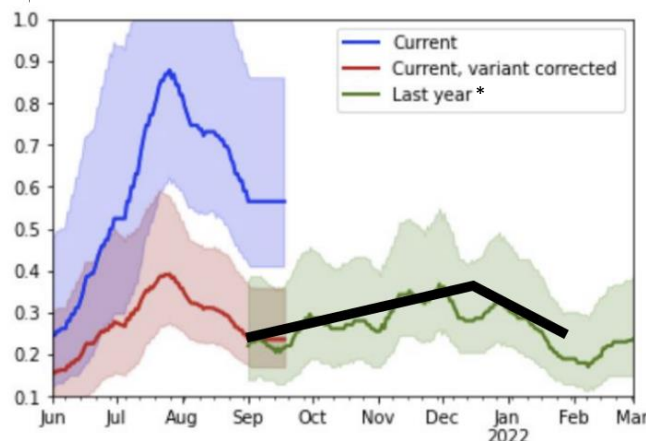
Scenarios – FallWinter2020 Description

September 2020 – February 2021 saw a strong wave of transmission

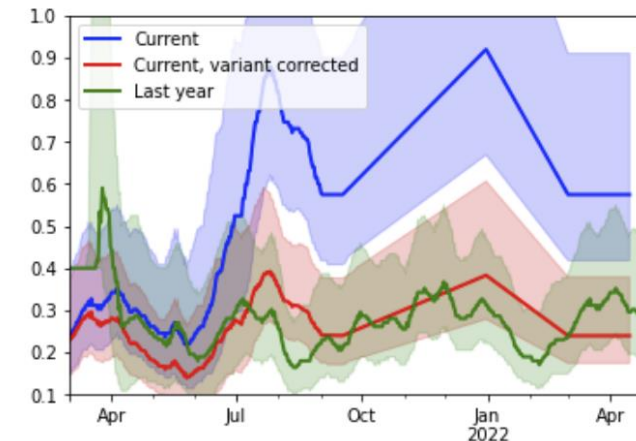
- We analyze previous Fall-Winter's wave vs. current Delta driven wave and observe surprising similarities
 - The distribution of fitted model transmissibility is nearly identical between these periods when corrected for Delta's increased transmissibility
- **FallWinter2020** tries to capture the “transmission drivers” from the past and use them as if they were to occur again this season but with Delta variant (compared to ancestral)
 - Use the above analysis of fitted model transmissibilities from Sept 2020 – Feb 2021 to guide the future transmissibility from Sept 2021 through Feb 2022, but add the enhanced transmissibility of Delta back in



Fitting:
Black line
represents the
coarsely fitted
base
transmissibility



* “Last year” is transplanted into 2021-22



Delta enhanced:
Blue trajectory
represents current
fitted and then
projected
transmissibility in
FallWinter2020

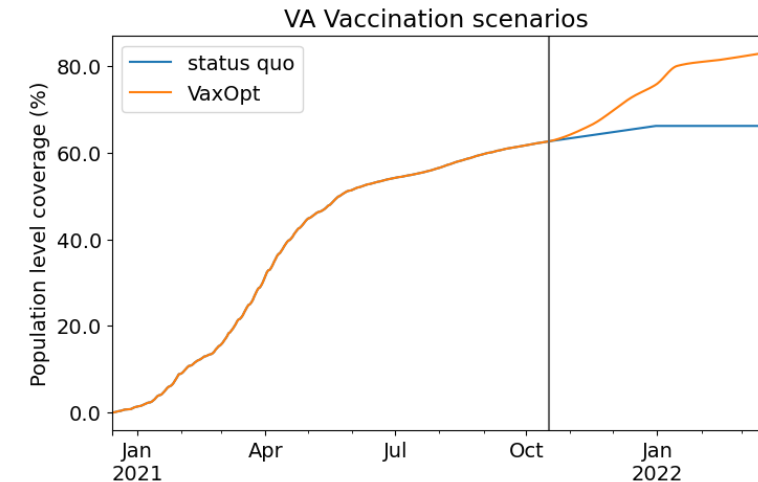
Scenarios – Vaccination Conditions

Vaccine Characteristics

- **Pfizer/Moderna:** 50% after first dose, 95% after second dose (3.5 week gap) **J & J :** 67% efficacy after first dose
- Delay to efficacy from doses is 14 days, immunity lasts at least 7m ([NEJM study](#))

Vaccine Administration Scenarios

- **Status quo (no label):** COVIDcast corrected acceptance estimates (statewide mean is ~80% adults, 65% of population) reached by end of October.
- **Optimistic (VaxOpt):** Expand VA mean acceptance to include “probably not” (~85% adults) with addition of childhood (5-11 yo) rollout starting in Nov 15th. This follows the same rates as observed of adolescents and results in a net increase of ~10% of population by end of February. Additionally, all counties guaranteed to reach a minimum of 65%, max of 95% by end of December
- Acceptance at county level = regional acceptance +/- relative current vax
- Front-loaded rollout (two-thirds of the remaining in half the time)



Date	Monthly		Cumulative	
	status quo	VaxOpt	status quo	VaxOpt
12/31/20	110.2K	110.2K	110.2K	110.2K
1/31/21	649.8K	649.8K	760.0K	760.0K
2/28/21	561.7K	561.7K	1.3M	1.3M
3/31/21	1.3M	1.3M	2.6M	2.6M
4/30/21	1.2M	1.2M	3.8M	3.8M
5/31/21	575.8K	575.8K	4.4M	4.4M
6/30/21	243.0K	243.0K	4.6M	4.6M
7/31/21	198.2K	198.2K	4.8M	4.8M
8/31/21	271.6K	271.6K	5.1M	5.1M
9/30/21	177.4K	177.4K	5.3M	5.3M
10/31/21	145.0K	249.9K	5.4M	5.5M
11/30/21	110.5K	432.3K	5.5M	6.0M
12/31/21	122.3K	507.6K	5.7M	6.5M
1/31/22	0	446.2K	5.7M	6.9M
2/28/22	0	103.2K	5.7M	7.0M
3/31/22	0	67.6K	5.7M ¹⁴	7.1M

Projection Scenarios – Combined Conditions

Name	Txm Controls	Vax	Description
Adaptive	C	SQ	Likely trajectory based on conditions remaining similar to the current experience
Adaptive-VaxOpt	C	VO	Vaccination through October reaches an optimistically high level of expanded coverage (85%)
Adaptive-SurgeControl	25%	SQ	Transmission rates in the next month reduced through increased control from non-pharmaceutical interventions, with status quo vax and Delta
Adaptive-FallWinter2020	FallWinter 2020	SQ	Transmission rates coarsely follow the rates from last September through this February but are boosted by Delta's enhanced transmissibility
Adaptive-FallWinter2020-VaxOpt	FallWinter 2020	VO	Transmission rates coarsely follow the rates from last September through this February but are boosted by Delta's enhanced transmissibility, with optimistic vax

Transmission Controls:

C = Current levels persist into the future

25% = Transmission rates are reduced by 25% with a gradual introduction, concluding in 4 weeks

FallWinter2020 = Transmission rates from Sept 2020 – Feb 2021 are coarsely replayed but boosted by Delta's increased transmissibility

Vaccinations:

SQ = Status quo acceptance leads to low rates of vaccination through the summer

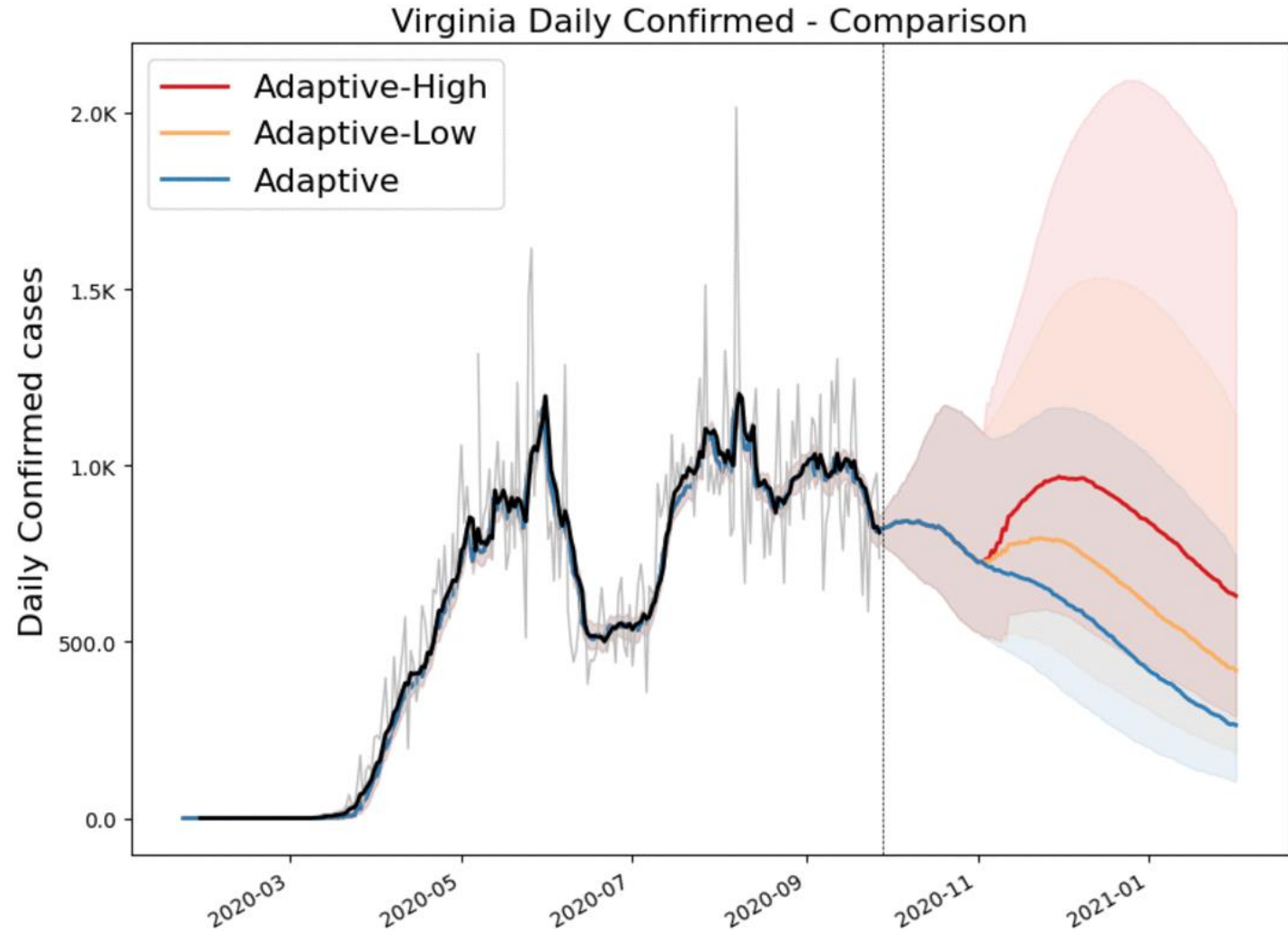
VO = Vaccination acceptance optimistically expands with increased rates through the summer

Review of “A Year of Projections”

Confirmed case Projections

Adaptive Approach with associated other projections

Sept 30th, 2020 to Oct 13th, 2021

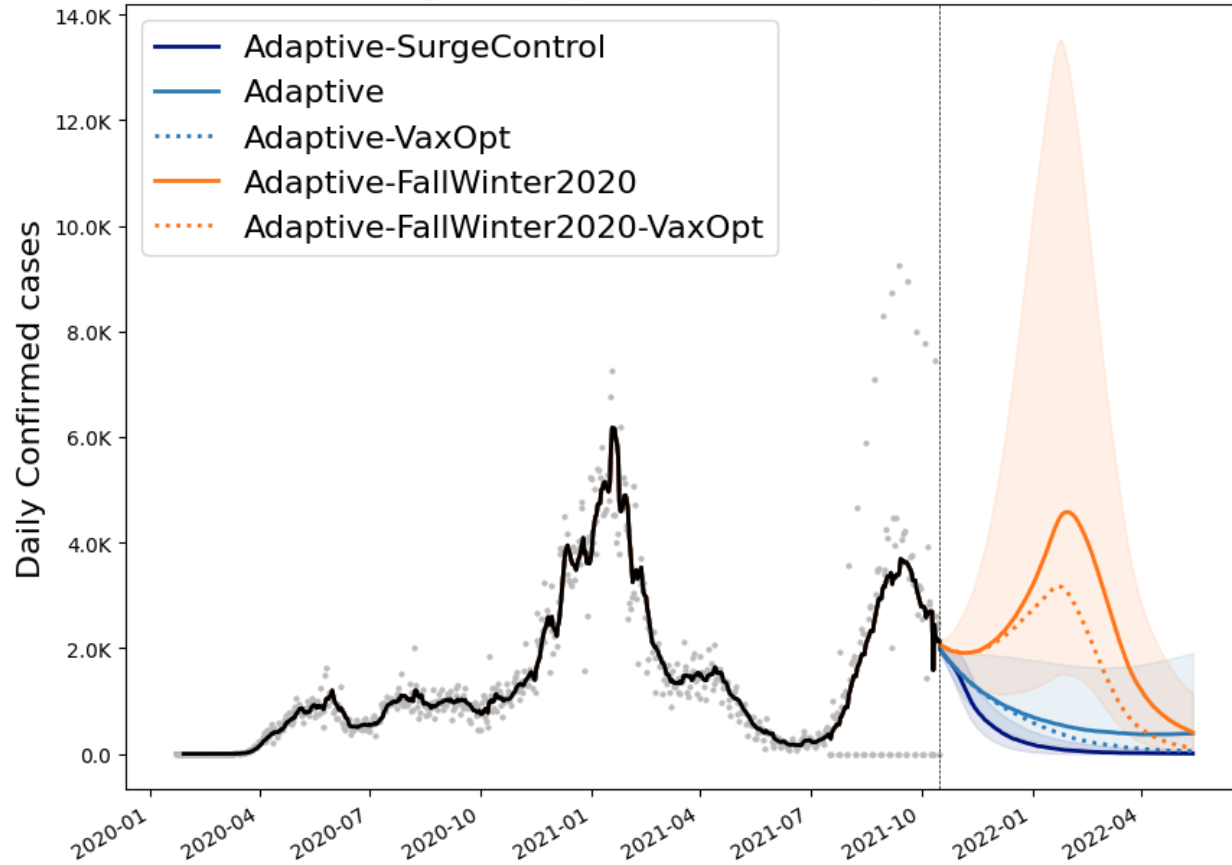


Model Results

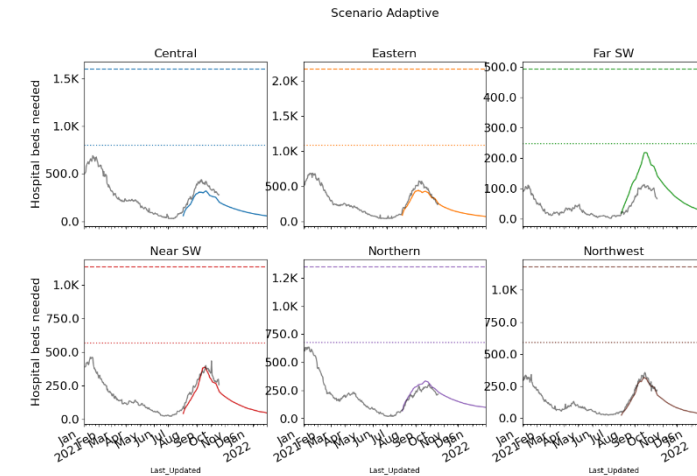
Outcome Projections

Confirmed cases

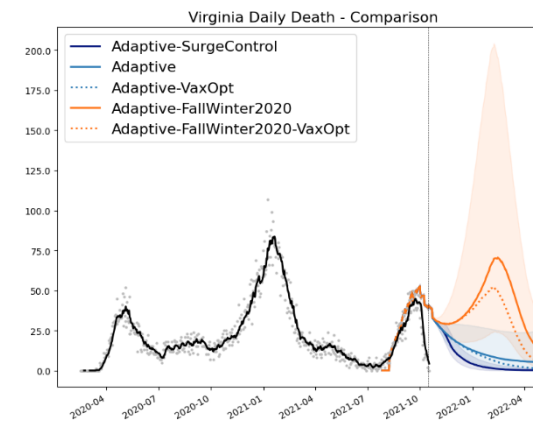
Virginia Daily Confirmed - Comparison



Estimated Hospital Occupancy

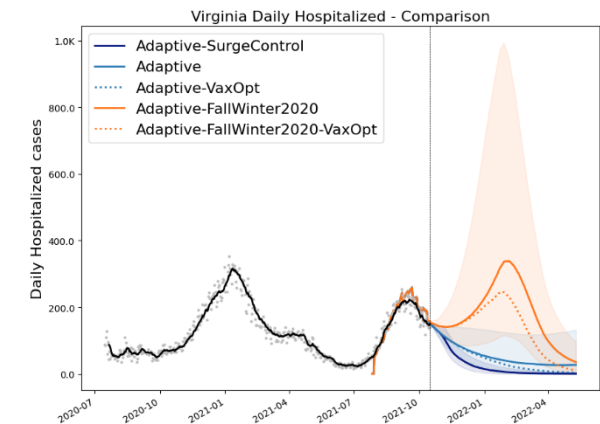


Daily Deaths



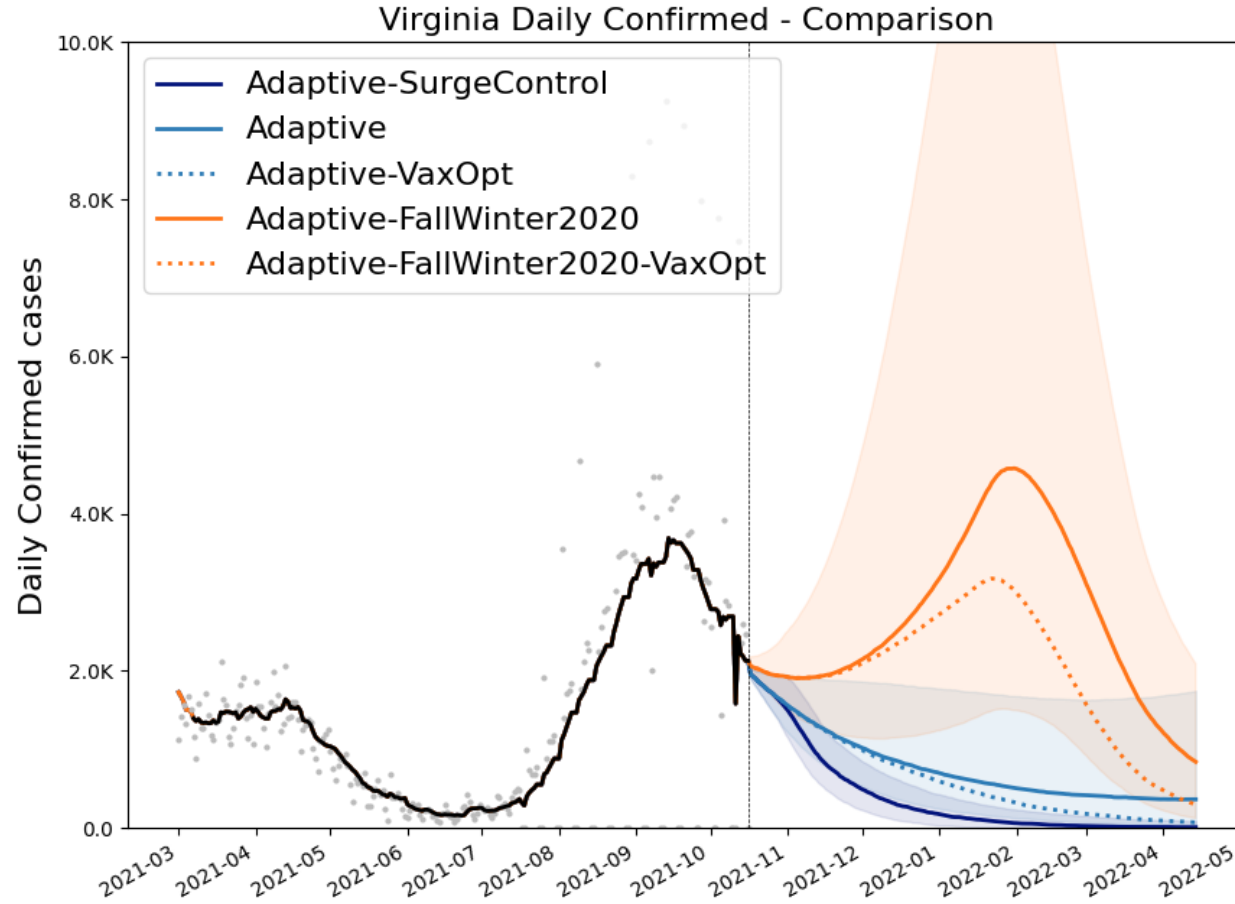
Death ground truth from VDH "Event Date" data, most recent dates are not complete

Daily Hospitalized

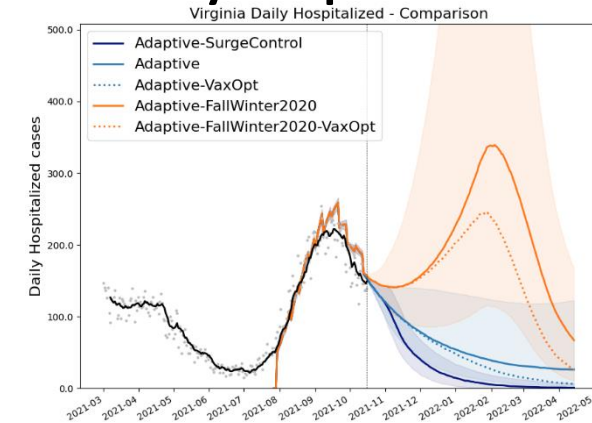


Outcome Projections – Closer Look

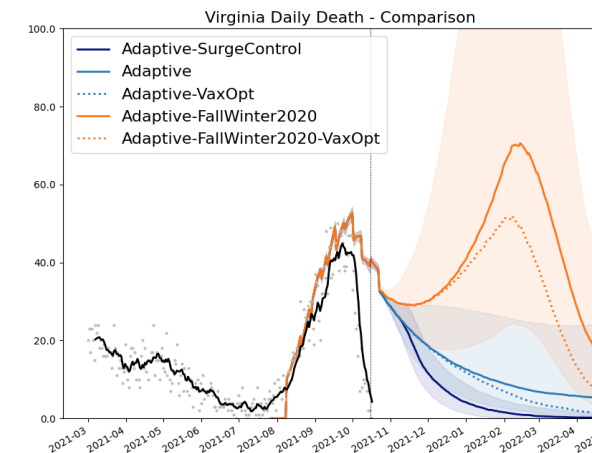
Confirmed cases



Daily Hospitalized



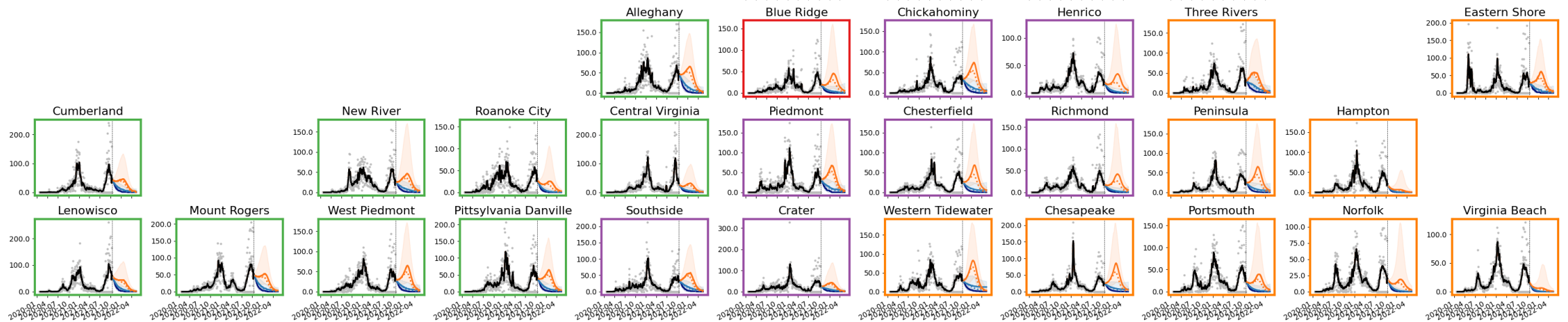
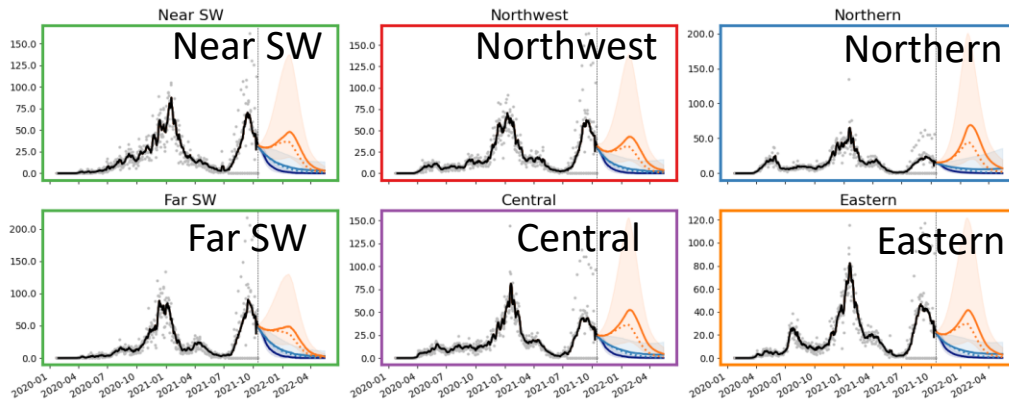
Daily Deaths



Death ground truth from VDH "Event Date" data, most recent dates are not complete

Detailed Projections: All Scenarios

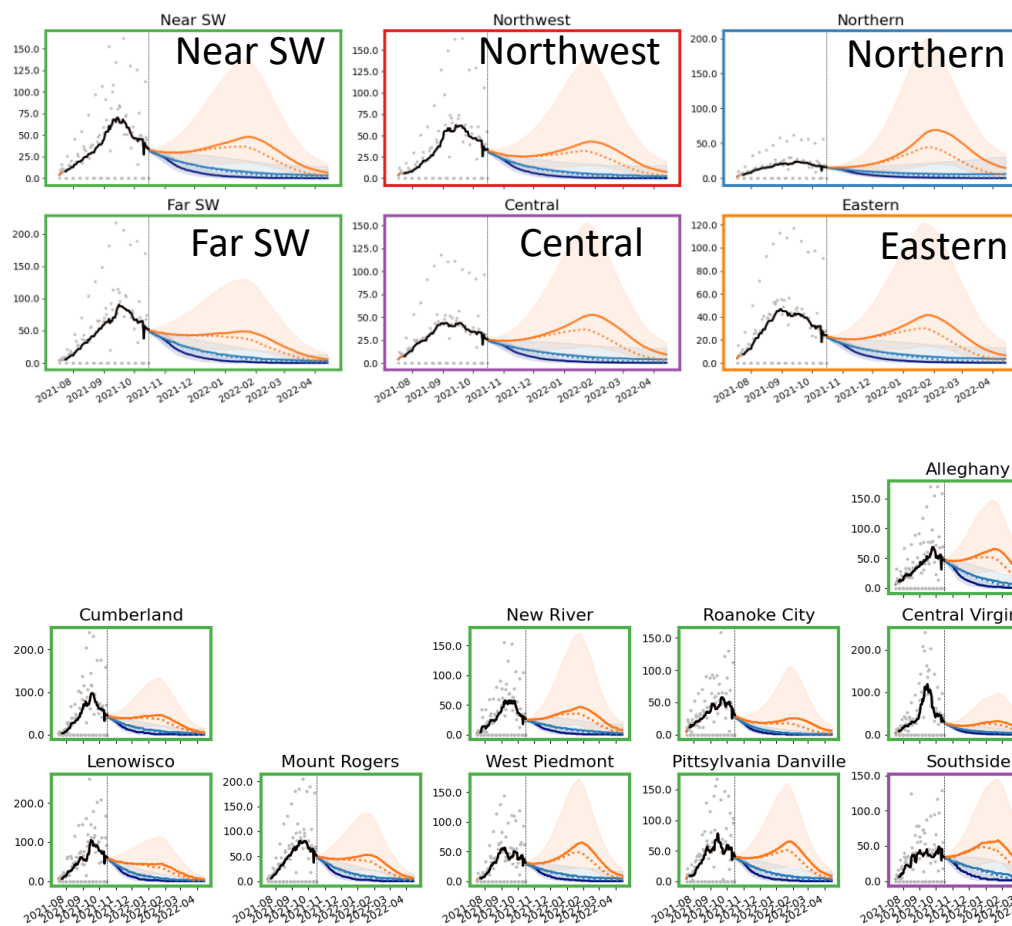
Projections by Region



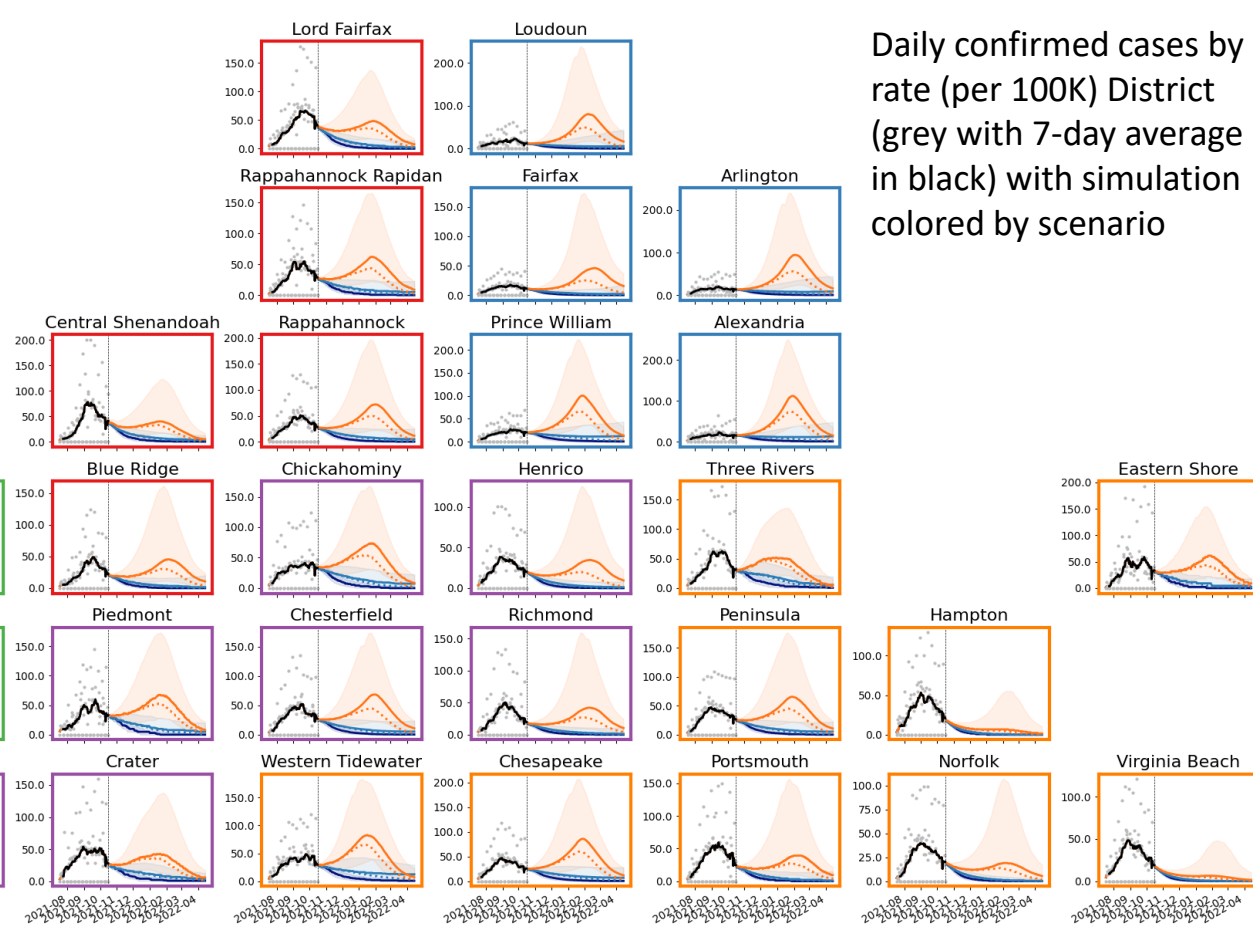
Daily confirmed cases)
by rate (per 100K)
District (grey with 7-day
average in black) with
simulation colored by
scenario

Detailed Projections: All Scenarios - Closer Look

Projections by Region



Projections by District

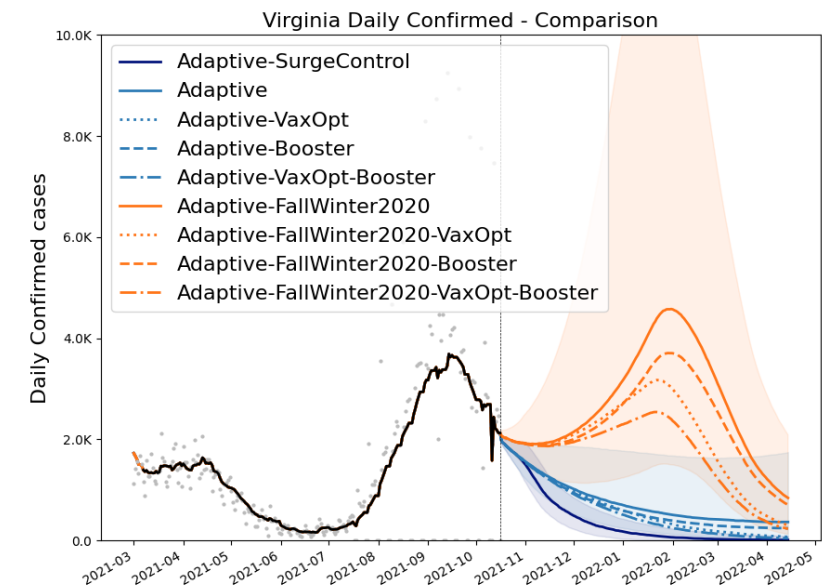
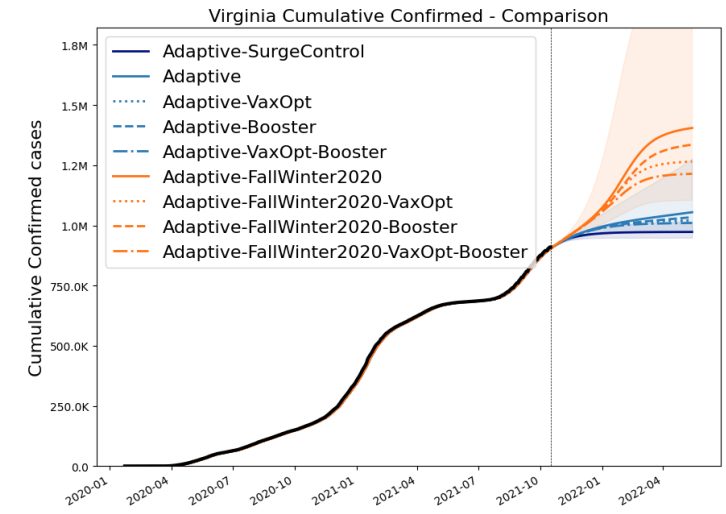


Daily confirmed cases by rate (per 100K) District (grey with 7-day average in black) with simulation colored by scenario

Impact of Expanded Vaccine Coverage & Boosted Immunity

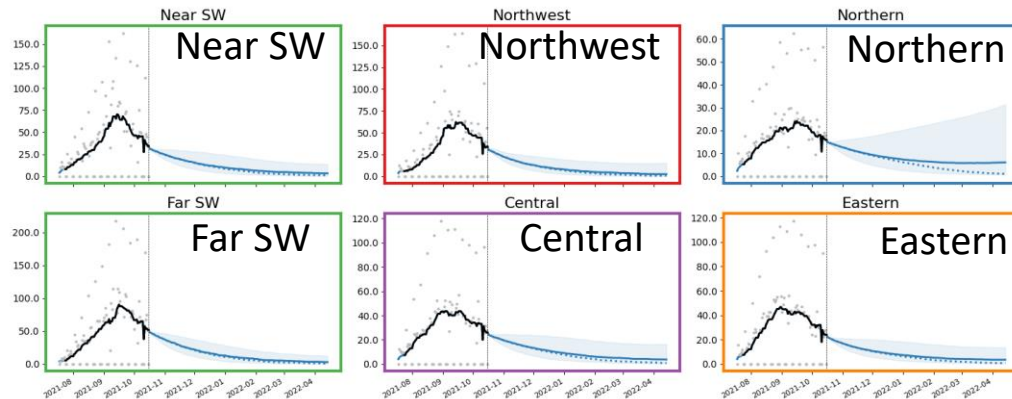
Vaccination eligibility is expanding (3rd doses, 5-11 year olds, increased acceptance).

- These estimates are preliminary
- 3rd doses: Estimate 40% uptake after 6 months of initial vax, returning waned immunity back to 95% (calibrated to observed additional doses)
- Third doses alone may reduce case counts by ~20K, VaxOpt alone by ~35K, and combined ~45K
- When challenged with another FallWinter wave like 2020, the 3rd dose may reduce cases by ~70K, VaxOpt alone by ~140K, and combined by ~190K

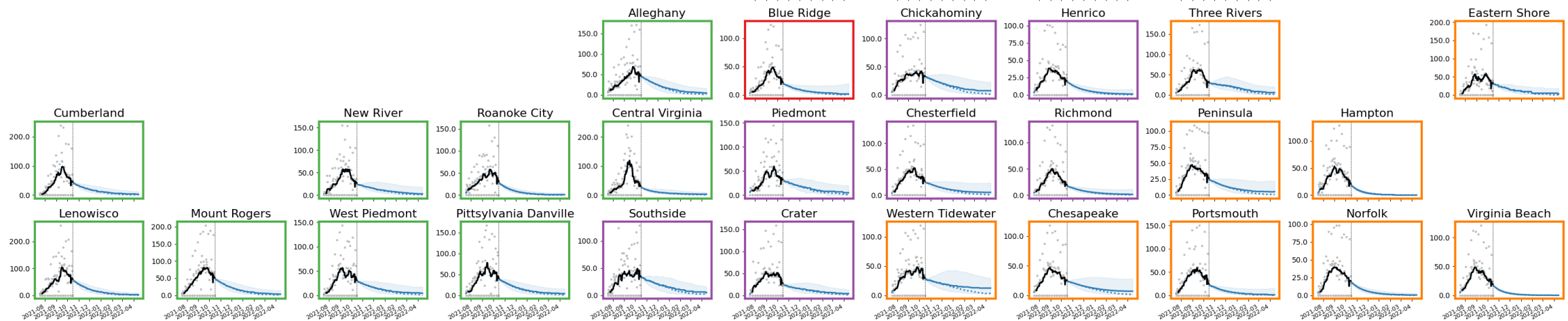


Detailed Projections: Adaptive with Vax Scenarios

Projections by Region



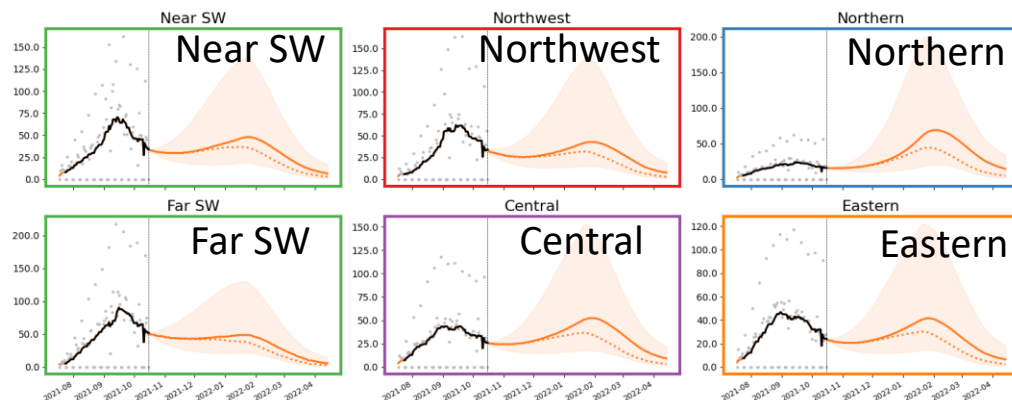
Projections by District



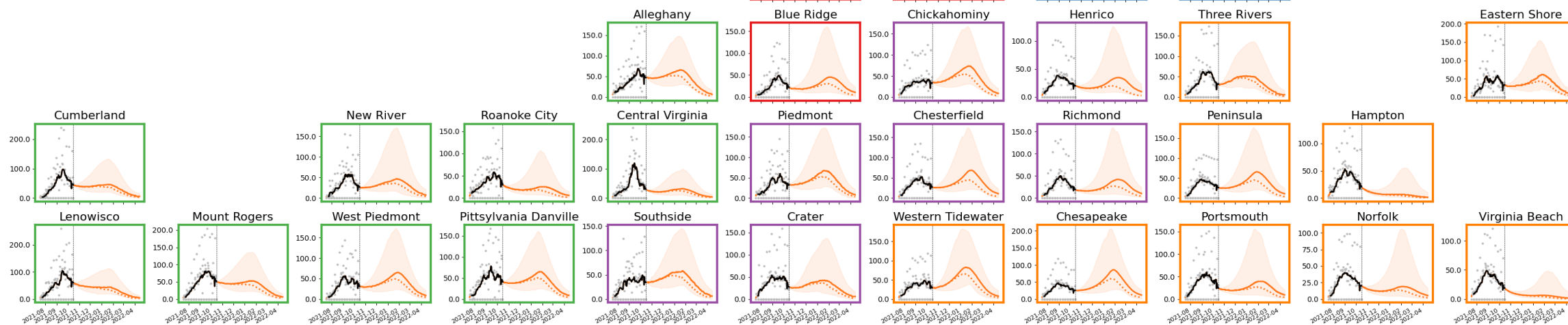
Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario

Detailed Projections: Adaptive-FallWinter2020 with Vax Scenarios

Projections by Region



Projections by District

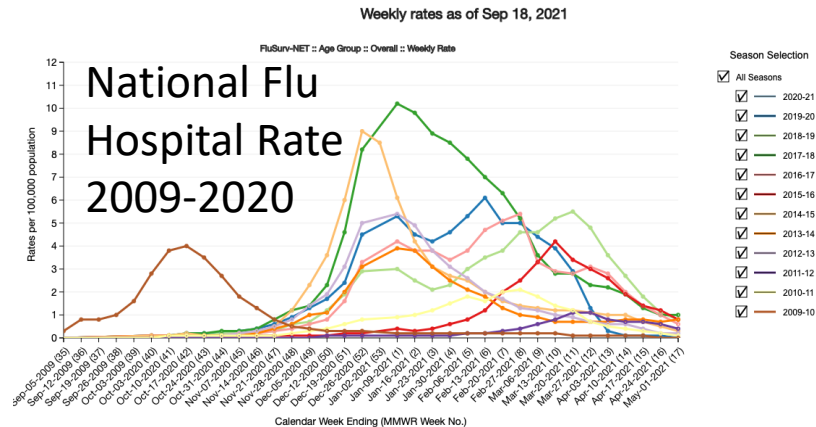


Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario

Impact of Influenza based on Previous Intense Flu Seasons

Augment COVID-19 daily hospitalizations with that of past Influenza seasons

- Include hybrid seasons that use timing of one season but are scaled by severity of another
- Due to limited historical data on Virginia flu hospitalizations currently using national rates applied to VA population



<https://gis.cdc.gov/GRASP/Fluview/FluHospRates.html>

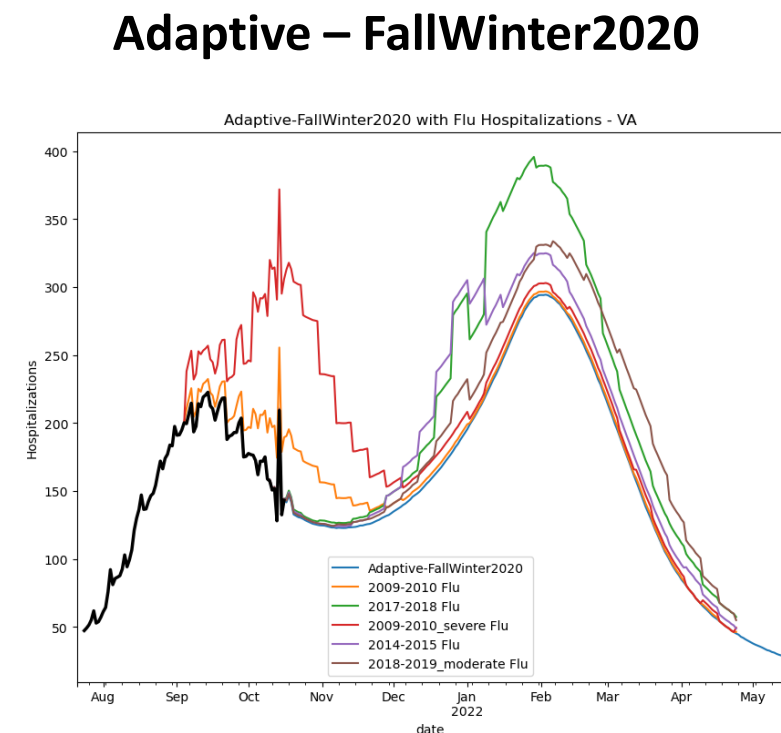
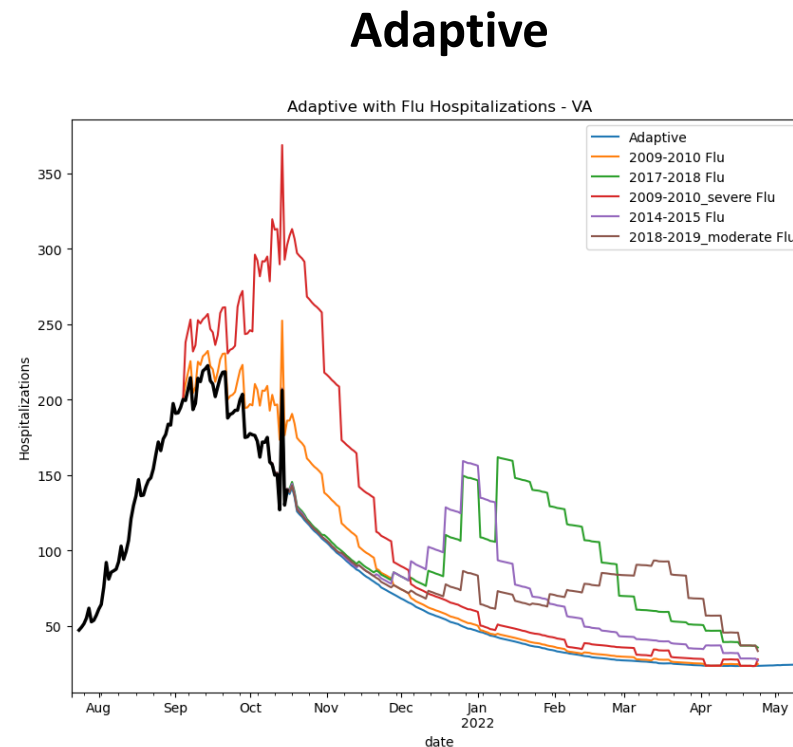
2009-10 – Pandemic 2009 H1N1 season

2017-18 – Timing and severity of 2017-18 season

2009-10_severe – Timing of 2009 pandemic (early) with the severity of the 2017-18 season

2014-15 – Timing and severity of 2014-15 season

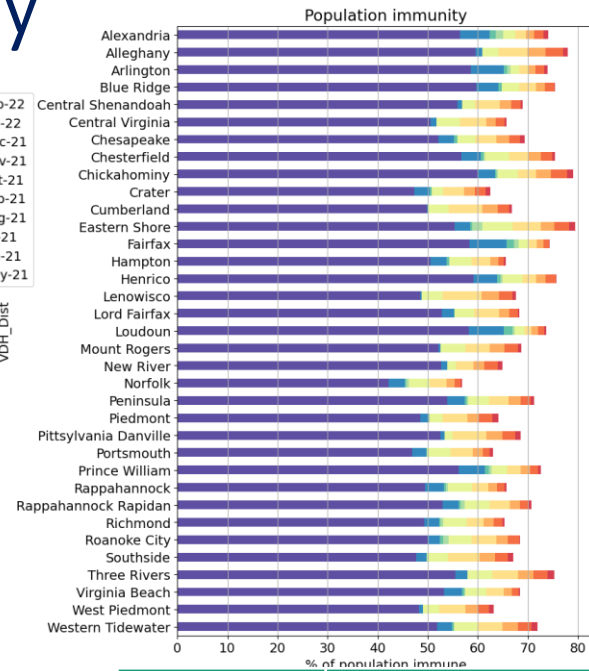
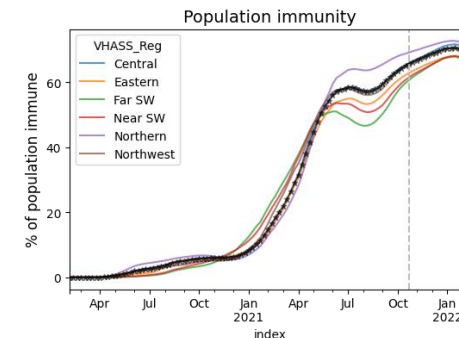
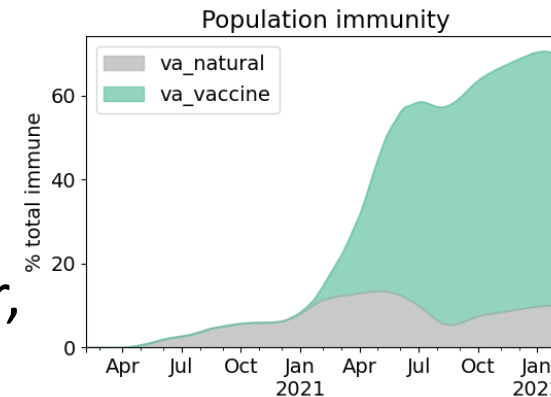
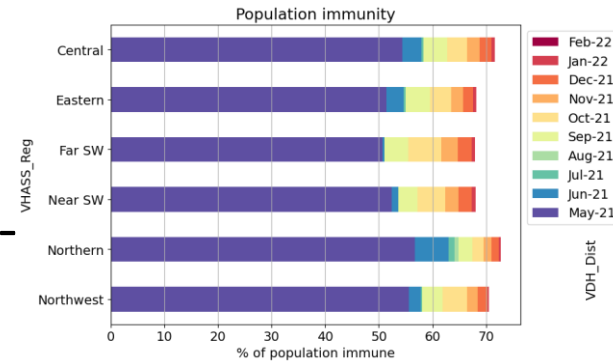
2018-19_moderate – Timing of 2018-19 (late) season with severity of 2014-15



Virginia's Progress on Population Immunity

Natural Immunity and Vaccines combine to produce a population level of immunity

- Duration of immunity from infection with SARS-CoV2 still not well understood
 - We assume a conservative 6 month period of protection for these calculations
 - Do **not** factor in variant immune escape
 - Natural immunity is well calibrated to recent seroprevalence surveys
- Vaccine induced immunity is likely to last longer, we assume indefinite protection
 - This also assumes that all administered vaccines remain protective against current and future variants
- Population immunity depends on a very high proportion of the population getting vaccinated
 - Current models track measured seroprevalence



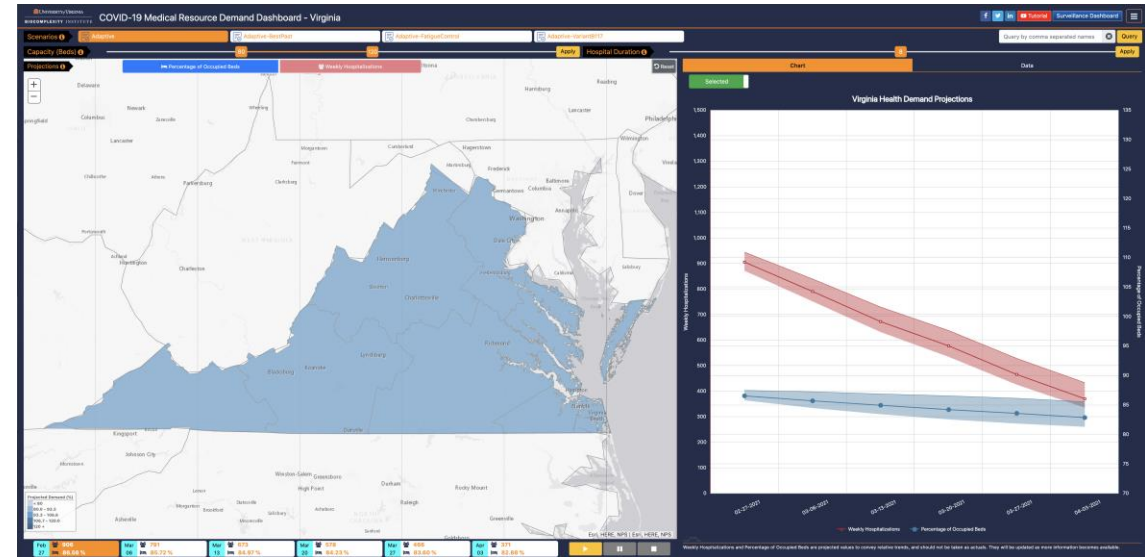
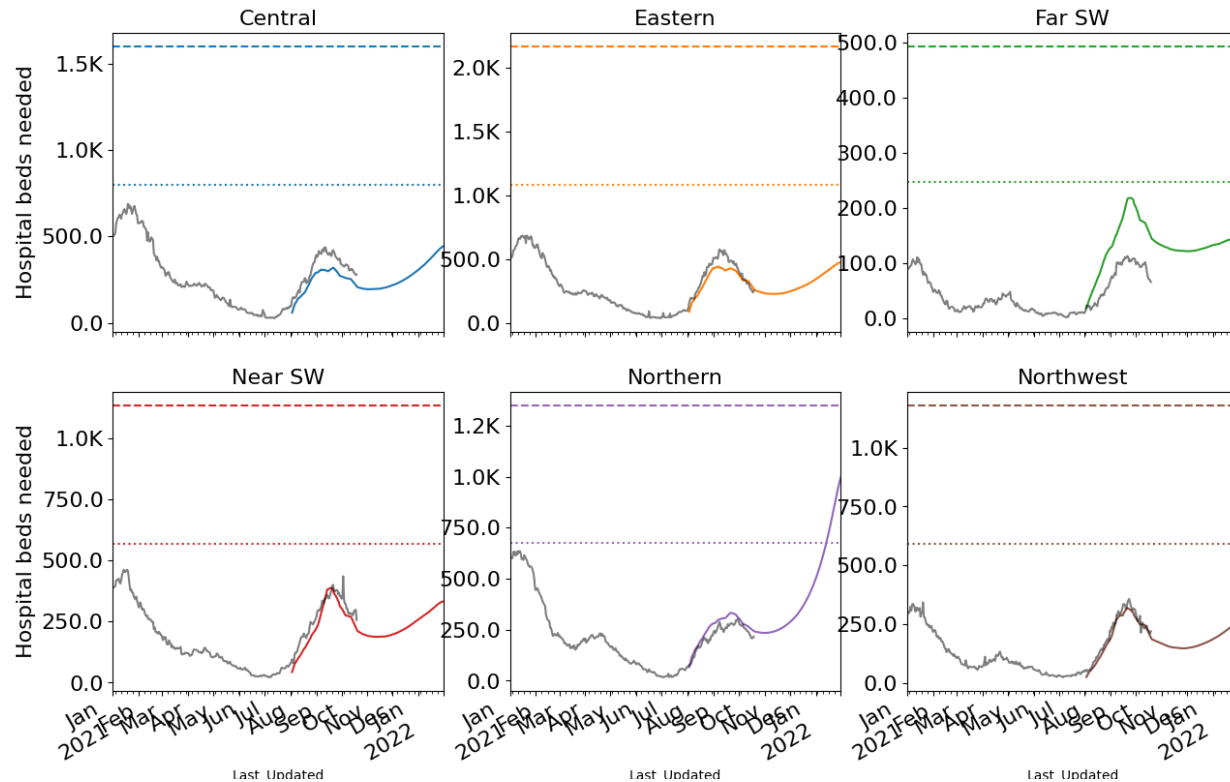
Region	% pop immune (est.)*
Central	65%
Eastern	62%
Far SW	60%
Near SW	61%
Northern	69%
Northwest	65%
Virginia	65%

* As of Oct 17, 2021 for entire population

Hospital Demand and Bed Capacity by Region

Capacities* by Region – Adaptive FallWinter2020

COVID-19 capacity ranges from 80% (dots) to 120% (dash) of total beds



<https://nssac.bii.virginia.edu/covid-19/vmrddash/>

Adaptive FallWinter2020 scenario shows that even with Delta enhanced severity:

- No regions should exceed their surge capacities
- Some regions may exceed initial capacities

* Assumes average length of stay of 8 days

Key Takeaways

Projecting future cases precisely is impossible and unnecessary.

Even without perfect projections, we can confidently draw conclusions:

- **Case rates in Virginia continue to decline, with nearly all districts declining as well; case rates remain high and the rate of decline remains steady**
- VA 7-day mean daily incidence is slightly down to 24/100K from 29/100K; US is also slightly down to 25/100K (from 28/100K)
- Projections show continued decline across the board
- Future case growth remains possible, however, when tested with transmission drivers from last year
- Recent updates:
 - Analysis to show potential impact of Influenza based on past seasons
 - Updated vaccination schedules, adjusted 3rd dose uptake and 5-11 year old timing
 - Adjustment to higher levels of assumed immunity waning (natural and vaccine)

The situation continues to change. Models continue to be updated regularly.

Additional Analyses

Weekly Cases and Hospitalizations

Weekly confirmed cases

Week Ending	Adaptive	Adaptive-VaxOpt	Adaptive-SurgeControl	Adaptive-FallWinter 2020	Adaptive-FallWinter 2020-VaxOpt
10/17/21	14646	14646	14646	14751	14751
10/24/21	12898	12894	12892	14070	14075
10/31/21	11619	11598	11476	13596	13602
11/7/21	10450	10406	9466	13390	13390
11/14/21	9410	9353	7122	13448	13419
11/21/21	8513	8410	5390	13730	13644
11/28/21	7729	7571	4230	14338	14126
12/5/21	7045	6819	3349	15198	14812
12/12/21	6405	6082	2612	16343	15615
12/19/21	5900	5478	2048	17776	16560
12/26/21	5418	4881	1655	19544	17628
1/2/2022	5014	4322	1318	21618	18736
1/9/2022	4618	3812	1036	24082	19866
1/16/2022	4314	3340	848	26928	21020

Weekly Hospitalizations

Week Ending	Adaptive	Adaptive-VaxOpt	Adaptive-SurgeControl	Adaptive-FallWinter 2020	Adaptive-FallWinter 2020-VaxOpt
10/17/21	1149	1149	1149	1166	1166
10/24/21	990	990	990	1051	1051
10/31/21	891	890	889	1009	1009
11/7/21	805	803	767	991	991
11/14/21	727	723	598	989	989
11/21/21	659	653	446	1007	1003
11/28/21	598	589	348	1045	1035
12/5/21	547	535	276	1103	1085
12/12/21	497	478	217	1180	1145
12/19/21	456	432	169	1279	1218
12/26/21	420	388	135	1399	1299
1/2/2022	387	348	108	1544	1390
1/9/2022	358	308	86	1709	1480
1/16/2022	332	272	70	1908	1573

Overview of relevant on-going studies

Other projects coordinated with CDC and VDH:

- **Scenario Modeling Hub:** Consortium of academic teams coordinated via MIDAS / CDC to that provides regular national projections based on timely scenarios
- **Genomic Surveillance:** Analyses of genomic sequencing data, VA surveillance data, and collaboration with VA DCLS to identify sample sizes needed to detect and track outbreaks driven by introduction of new variants etc.
- **Mobility Data driven Mobile Vaccine Clinic Site Selection:** Collaboration with VDH state and local, Stanford, and SafeGraph to leverage anonymized cell data to help identify

COVID-19 Scenario Modeling Hub

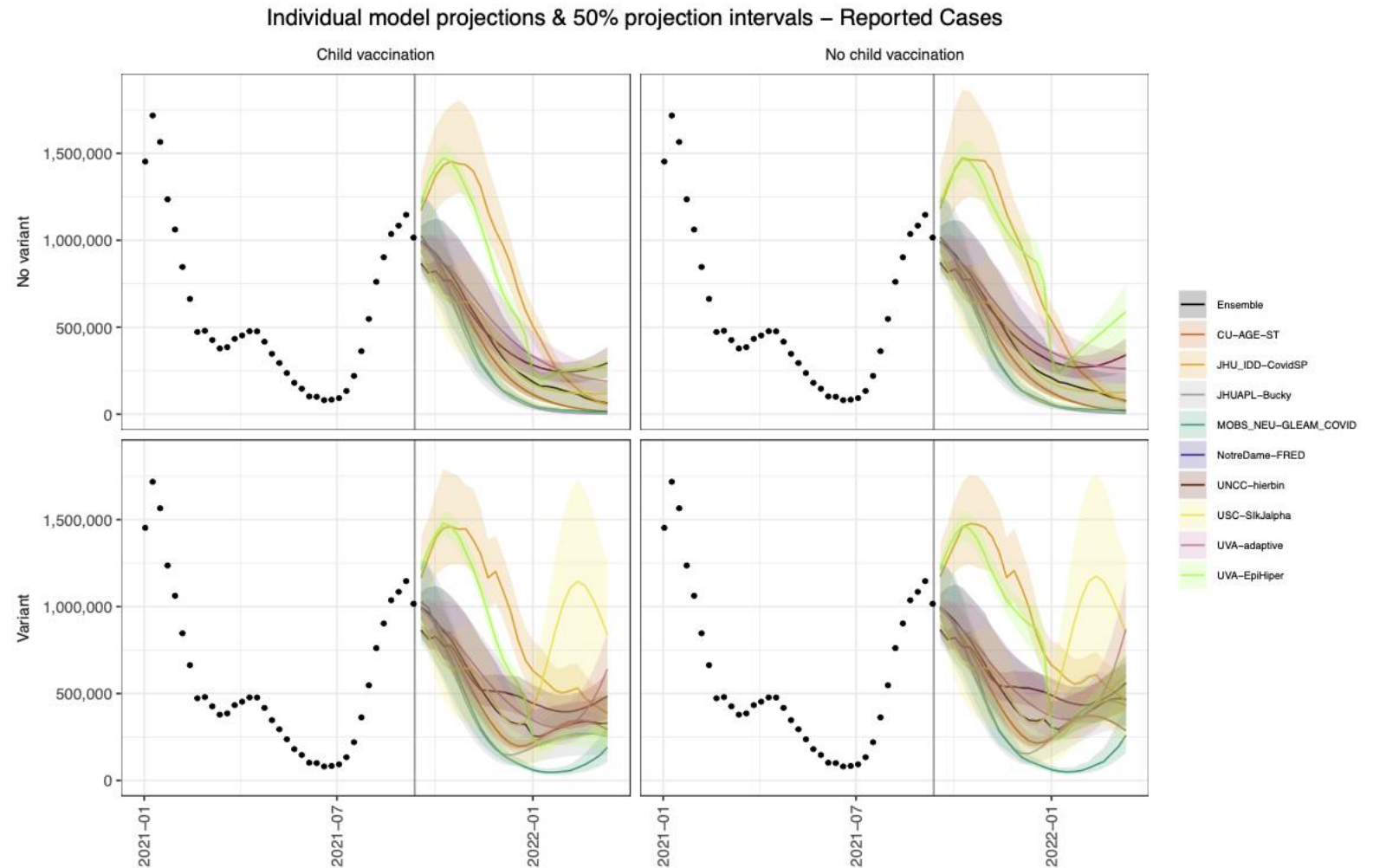
Collaboration of multiple academic teams to provide national and state-by-state level projections for 4 aligned scenarios that vary vaccine rates (high – low) and impact of the Delta variant (high and low)

- Round 9 released to assist in support of 5-11 vax consideration (ACIP meeting Sept 22-23)

- Rounds 4-8 now available

Round 4 Results were published May 5th, 2021 in [MMWR](#)

<https://covid19scenariomodelinghub.org/viz.html>



COVID-19 Scenario Modeling Hub – Round 7

Round 7 scenarios explore the effects of a variant similar to Delta (B.1.617.2) against different backgrounds of vaccination. Includes some vax escape

Vaccinations in 5-11 start in Nov

- Follows same rates as adolescents

Emerging Variant Impact (5% prevalence on Nov 15)

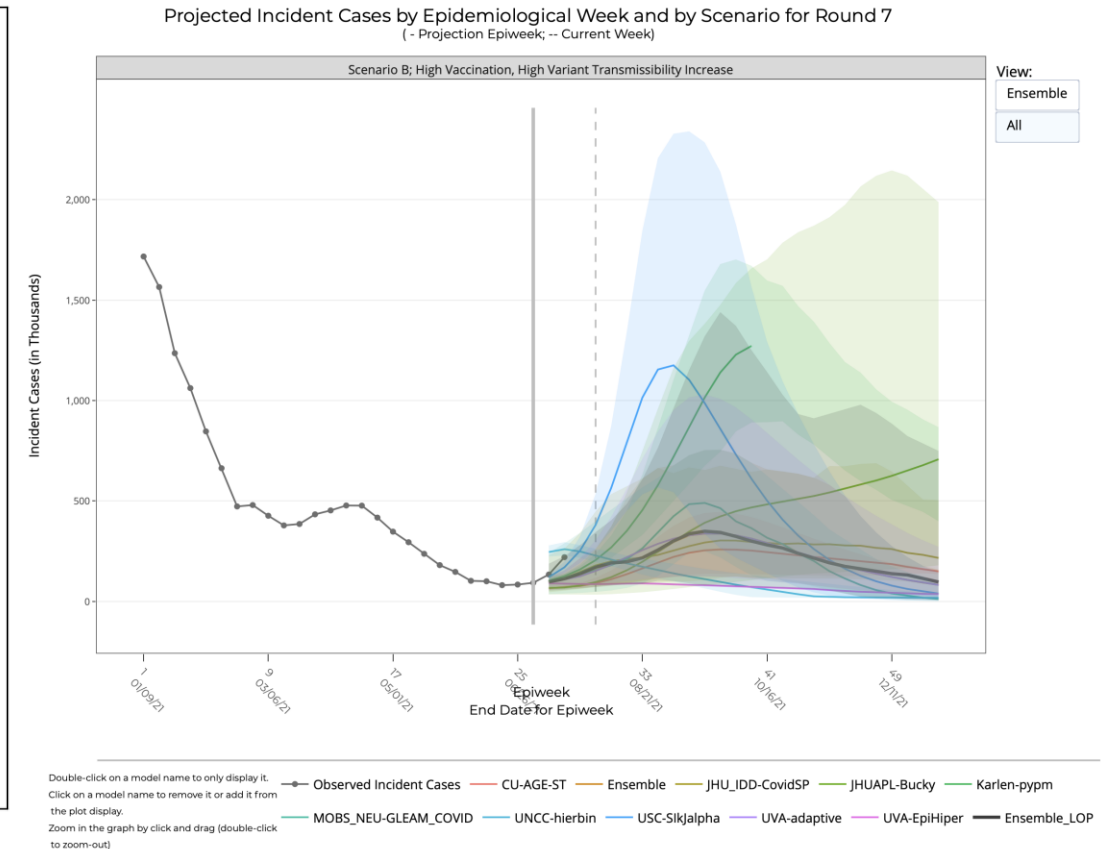
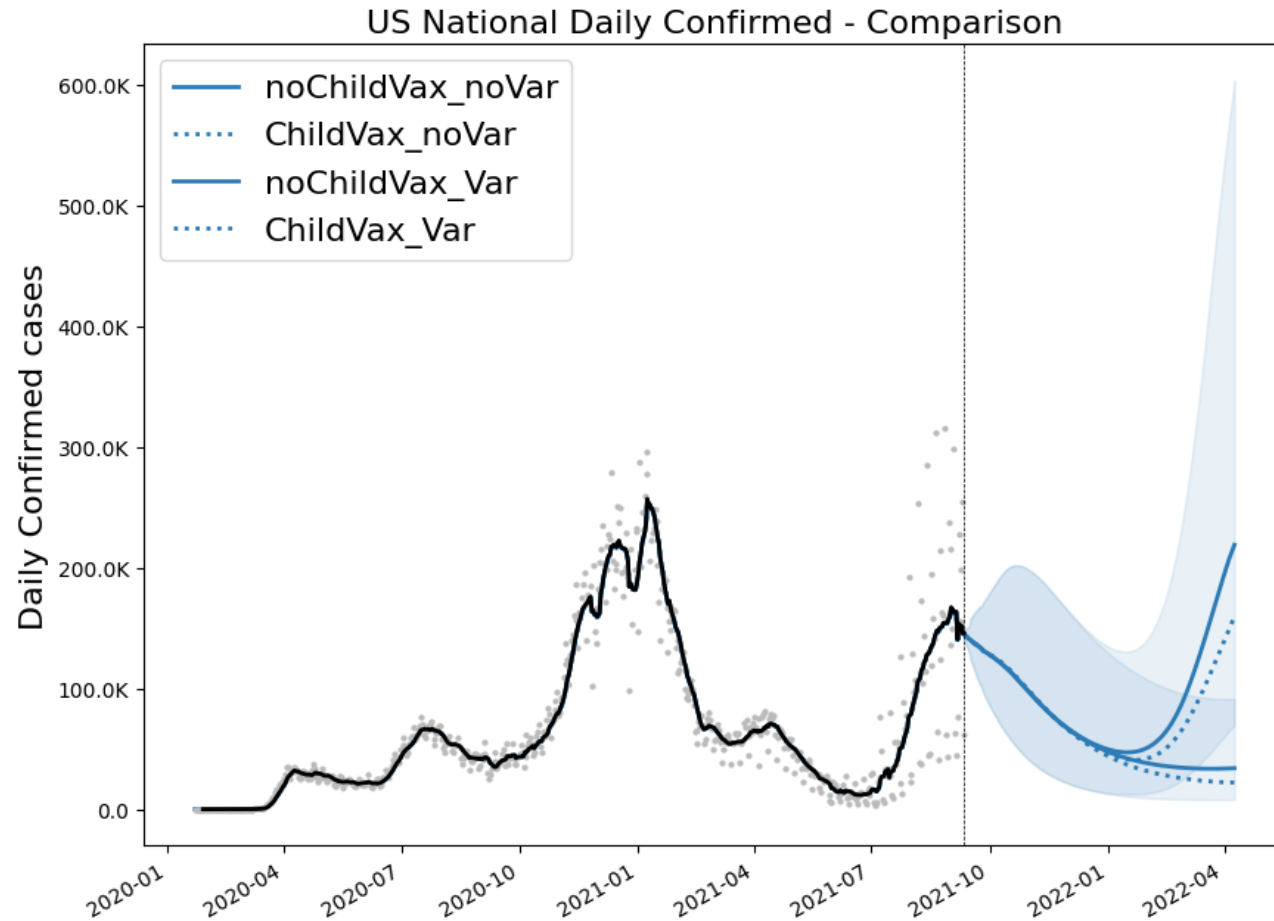
- 50% boost as it eventually predominates

We consider a 2x2 scenario design, where childhood vaccination (5-11 years) is on the first axis, and a change in virus transmissibility is on the second axis. The second axis reflects a stress test, illustrating the potential impact of a new variant arising during the projection period:

	The same mix of variants circulate throughout the projection period. No change in virus transmissibility.	A more transmissible variant emerges, comprising 1% of circulating viruses on Nov 15 . The new variant is 1.5X as transmissible as viruses circulating at the beginning of the projection period.
Vaccination among 5-11yrs is approved and immunization begins on Nov 1. Each state's uptake rate reflects the percent coverage increases observed for 12-17-year-olds since distribution began on May 13.	A	C
No vaccination for children under 12	B	D

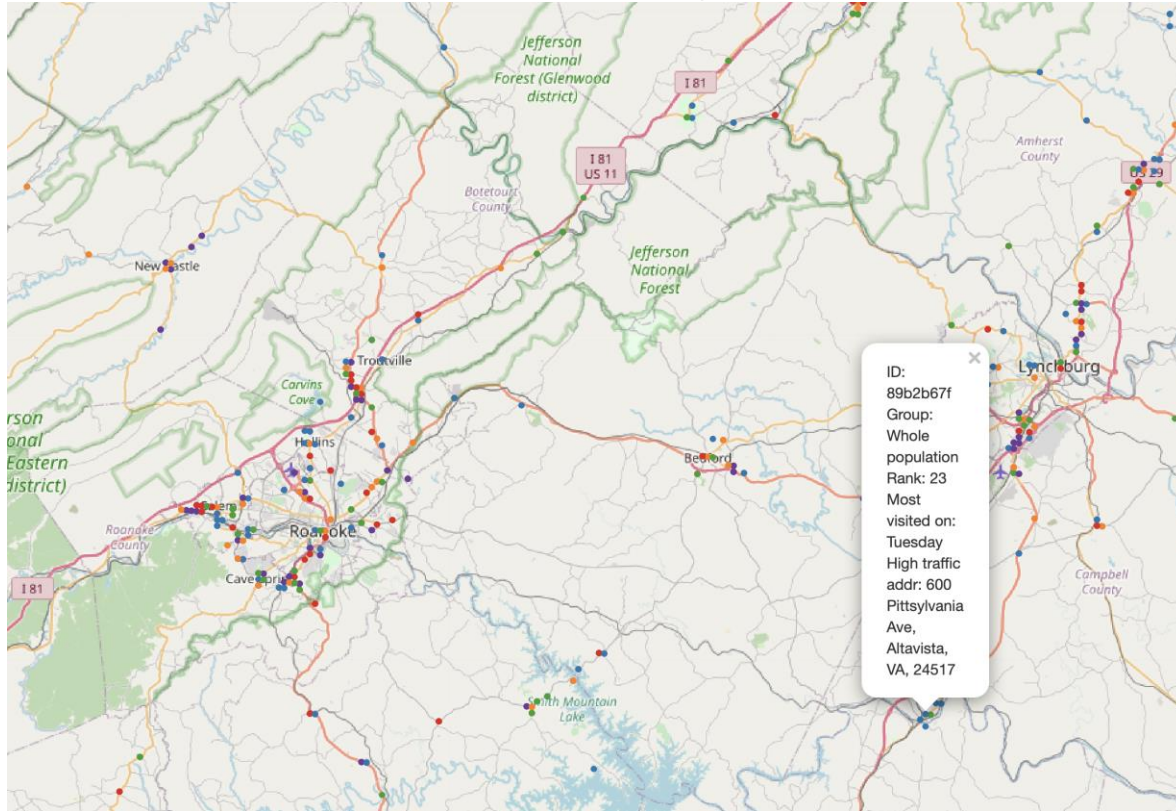
<https://covid19scenariomodelinghub.org/viz.html>

Modeling Hub – Round 9 Prelim Results



Data Recommended Mobile Vax Clinic Sites

Detailed and Timely Locations



Data Delivered and Disseminated to Locals

Provides a list of areas most visited by a given demographic group based on SafeGraph mobility data that links visits to specific sites and the home Census Block Group of the anonymized visitors

Demographic Groups: Black, Lantinx, Young Adults (20-40), Unvaccinated, and Whole Population

Data Included: Rank, Weight, most visited Day of Week, Highly Visited Address, and Lat-Long of area

Goal: Provide frequently visited locations based on populations and vaccination levels one desires to reach

Example: List of location in the Southside frequented by 20-40 year olds

Overlap of locations between groups



- 
- UNIVERSITY

Estimating Daily Reproductive Number

October 11th Estimates

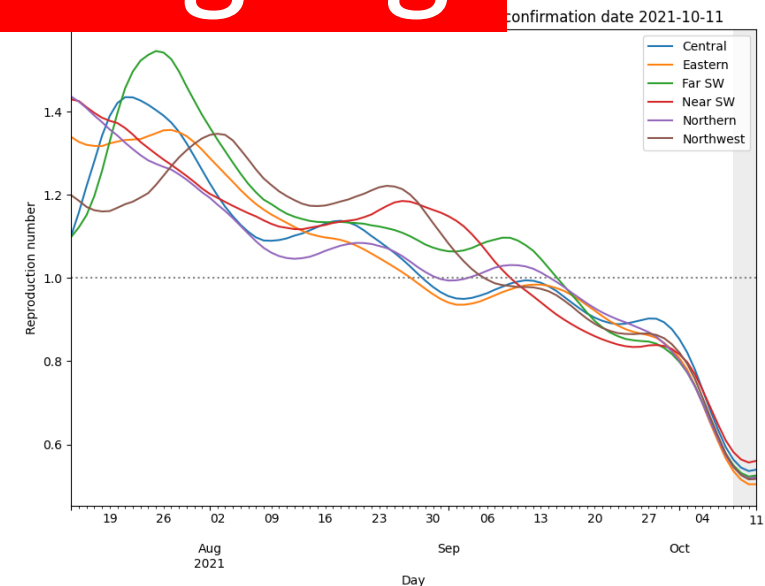
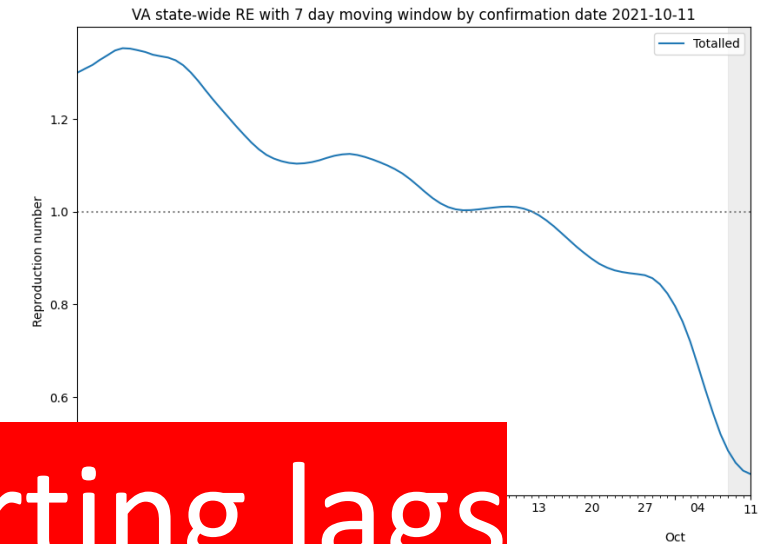
Region	Date Confirmed R_e	Date Confirmed Diff Last Week
State-wide	0.434	-0.581
Central	0.491	-0.550
Eastern		
Far SW		
Near SW	0.492	-0.491
Northern	0.462	-0.527
Northwest	0.456	-0.564

Erroneous due to reporting lags

Methodology

- Wallinga-Teunis method (EpiEstim¹) for cases by confirmation date
- Serial interval: updated to discrete distribution from observations (mean=4.3, Flaxman et al, Nature 2020)
- Using Confirmation date since due to increasingly unstable estimates from onset date due to backfill

1. Anne Cori, Neil M. Ferguson, Christophe Fraser, Simon Cauchemez. A New Framework and Software to Estimate Time-Varying Reproduction Numbers During Epidemics. American Journal of Epidemiology, Volume 178, Issue 9, 1 November 2013, Pages 1505–1512, <https://doi.org/10.1093/aje/kwt133>



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Arindam Fadikar, Dave Higdon, Jiangzhuo Chen, Bryan Lewis, Srinivasan Venkatramanan, and Madhav Marathe. Calibrating a stochastic, agent-based model using quantile-based emulation. *SIAM/ASA Journal on Uncertainty Quantification*, 6(4):1685–1706, 2018.

Adiga, Aniruddha, Srinivasan Venkatramanan, Akhil Peddireddy, et al. "Evaluating the impact of international airline suspensions on COVID-19 direct importation risk." *medRxiv* (2020)

NSSAC. PatchSim: Code for simulating the metapopulation SEIR model. <https://github.com/NSSAC/PatchSim>

Virginia Department of Health. COVID-19 in Virginia. <http://www.vdh.virginia.gov/coronavirus/>

Biocomplexity Institute. COVID-19 Surveillance Dashboard. <https://nssac.bii.virginia.edu/covid-19/dashboard/>

Google. COVID-19 community mobility reports. <https://www.google.com/covid19/mobility/>

Biocomplexity page for data and other resources related to COVID-19: <https://covid19.biocomplexity.virginia.edu/>

Questions?

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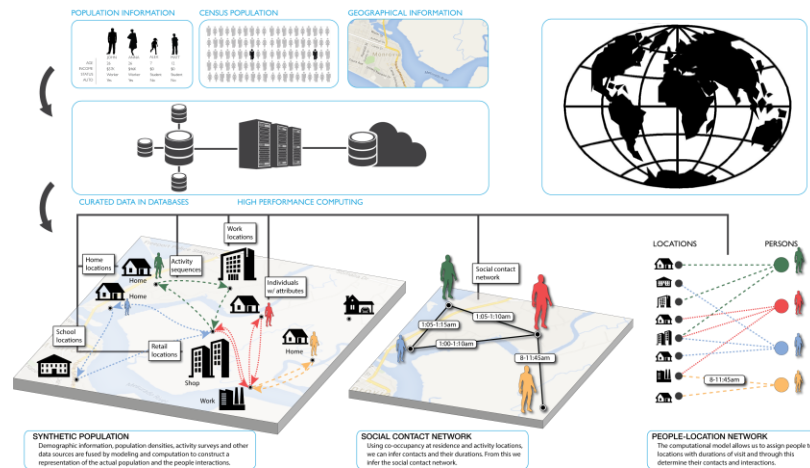
Aniruddha Adiga, Abhijin Adiga, Hannah Baek, Chris Barrett, Golda Barrow, Richard Beckman, Parantapa Bhattacharya, Jiangzhuo Chen, Clark Cucinell, Patrick Corbett, Allan Dickerman, Stephen Eubank, Stefan Hoops, Ben Hurt, Ron Kenyon, Brian Klahn, Bryan Lewis, Dustin Machi, Chunhong Mao, Achla Marathe, Madhav Marathe, Henning Mortveit, Mark Orr, Joseph Outten, Akhil Peddireddy, Przemyslaw Porebski, Erin Raymond, Jose Bayoan Santiago Calderon, James Schlitt, Samarth Swarup, Alex Telionis, Srinivasan Venkatramanan, Anil Vullikanti, James Walke, Andrew Warren, Amanda Wilson, Dawen Xie

Supplemental Slides

Agent-based Model (ABM)

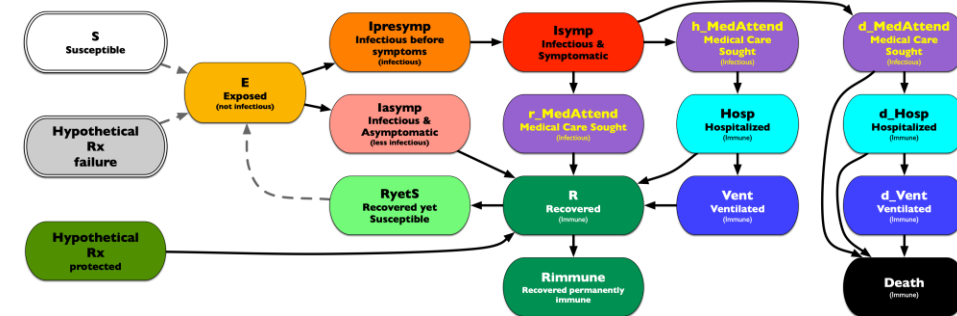
EpiHiper: Distributed network-based stochastic disease transmission simulations

- Assess the impact on transmission under different conditions
- Assess the impacts of contact tracing



Synthetic Population

- Census derived age and household structure
- Time-Use survey driven activities at appropriate locations



Detailed Disease Course of COVID-19

- Literature based probabilities of outcomes with appropriate delays
- Varying levels of infectiousness
- Hypothetical treatments for future developments